PB 198 779

RESEARCH TRIANGLE INSTITUTE

Contract No. CPA 70-60
RTI Project No. OU-534

December 1970

FINAL REPORT
FR-OU-534
Volume II

# USER'S MANUAL AUTOMATED PROCEDURES FOR ESTIMATING CONTROL COSTS AND EMISSION REDUCTIONS FOR SPECIFIED AIR POLLUTION SOURCES

by

H.S. Anderson, R.E. Paddock, R.O. Lyday,
M.E. Fogel, E.L. Hill, F.A. Ayer

*Prepared for:*
*Division of Economic Effects Research*
*Air Pollution Control Office*
*Environmental Protection Agency*

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INFORMATION SERVICE
Springfield, Va. 22151

297

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

PB 198 779

**STANDARD TITLE PAGE FOR TECHNICAL REPORTS**

1. Report No. APTD-0665

2. Gov't Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

User's Manual: Automated Procedures for Estimating Control Costs and Emission Reductions for Specified Air Pollution Sources Volume II

5. Report Date December 1970

6. Performing Organization Code

7. Author(s)

M. E. Fogel, R. E. Folsom, E. L. Hill, F. A. Ayer

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Division of Economic Effects Research
Air Pollution Control Office
Environmental Protection Agency
Research Triangle Park, North Carolina 27709

10. Project/Task/Work Unit No.

11. Contract/Grant No.

CPA 70-60

12. Sponsoring Agency Name and Address

Same as above

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstracts

A user 's manual is presented which facilitates the use and modification of the computer programs developed within this research project for estimating the costs and emissions of specified industrial air pollution sources. The output from each source program consists of emission estimates, both before and after control, as well as required control costs on a plant by plant basis. The manual describes the input requirements, operational characteristics, and output characteristics for each program.

17. Key Words and Document Analysis. (a). Descriptors

Computer programs
Cost estimates
Industrial wastes

17b. Identifiers/Open-Ended Terms

Air pollution control
Industrial emission sources

17c. COSATI Field/Group 13/B

18. Distribution Statement

Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class. (This Page) UNCLASSIFIED

21. No. of Pages 297

22. Price $3.00

FORM NBS-837(1-70)

RESEARCH TRIANGLE INSTITUTE
OPERATIONS RESEARCH AND ECONOMICS DIVISION
RESEARCH TRIANGLE PARK, NORTH CAROLINA

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# User's Manual
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# ABSTRACT

A user's manual is presented enabling other researchers to use and modify the computer programs developed within this research project for estimating the costs and emissions of specified industrial air pollution sources. The output from each source program consists of emission estimates, both before and after control, as well as required control costs on a plant by plant basis. The manual describes the input requirements, operational characteristics, and output characteristics for each program. A master report generating program was also developed. This program uses as input the output from one, all, or any combination of source programs; it generates summary data in the form of a single industry or multiple industry, and sums within a range of desired geographical areas. The area may be a single or combinations of Air Quality Control Regions or states. Again, the manual describes the input requirements, operational characteristics, and output characteristics of the report generating program so that the user has maximum flexibility in the use of the present system and, in addition, has the ability to redesign the system to his specific needs. Program listings are provided for all programs.

Published separately as a part of this research study are: (1) the main report that includes the estimates of the air pollution control costs and economic impact that will result from implementation of the Clean Air Act, as Amended (Volume I); and (2) a survey plan for obtaining plant and plant process information where such information is presently lacking (Volume III).

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## Volume II

## User's Manual

## Automated Costing Procedures for Estimating Control Costs and Emission Reductions for Specified Air Pollution Sources

## I. INTRODUCTION

This volume of the final report is devoted to a detailed description of the computer programs developed as specified in paragraph 3C, Exhibit A, Contract CPA 70-60:

> The contractor shall prepare complete computer programs and encode and record the basic data on punched cards. The goal of this automated ...cost analysis is ... to facilitate (calculations for) sensitivity analysis (based on) changes in selected parameters and thereby get a better idea of the total error involved in the estimate. These programs will most likely be used to facilitate the projection of costs for only the 1967 facilities.

Computer programs were written to calculate total investment costs, one annualized cost, and appropriate emissions as calculated for Calendar Year 1967 and the final year of implementation, for those emission sources listed in Table 1. Emission type(s) for each source category are also shown, and the appendix in which each program is described in detail is specified.

The following emission sources, which are included in the overall study (Volume I) have no associated computer programs: industrial boilers, commercial-institutional heating, residential heating, elemental phosphorus, rubber (tires), and mobile sources. The reasons that these programs were omitted are: (1) data available were inadequate to justify more than the most general calculation; and (2) control schemes as applied are too tenuous in a technological sense to be embedded in a computer program. Calculations for these sources were done manually by RTI personnel.

The overall system, which produces the final desired output of total costs and emissions and aggregates by metropolitan area is divided into three sequential stages. The first stage involves collection of data in as much detail as possible for each source considered, and the coding of the information gathered in the standard format for the "source program" which will use it. Each plant is identified by name and location, and by standard Region, State, Area, County (RSAC) code and special RSAC part code. The RSAC code is a four-character code developed by the National Resource Analysis Center to identify each county in the United States. The RSAC part code is a special one-character code used if different parts of a single county should fall into more than one metropolitan area.

Stage 2 uses the coded data with appropriate source program to calculate costs and emissions for each plant. The standard output of each source program is a listing of the results of the calculations for each plant with plant identification, plus punched cards in a standard format using Subroutine OUTFI (q.v.) for use in Stage 3. The standard punched-card format includes the RSAC code and RSAC part code. Departures from standard input or output procedures are described in the appendix for that particular source program.

The final stage involves (1) program MATCH which first, where necessary, converts RSAC code and RSAC part code to a metropolitan area number; (2) program SEARCH groups costs and emissions into as many as ten groups by metropolitan area code; (3) program PRINT calculates the implementation plan and produces the output summaries, growth estimates, and implementation schedules. The appendices in which these programs are described are noted in Table 1.

All programs are written in the FORTRAN language, and were initially used on the Bunker-Ramo 340 computer owned and operated by RTI. Every attempt has been made, at the sacrifice of programming and run-time efficiency, to make these programs directly compatible with any computer equipped with a FORTRAN II or higher level compiler, including avoidance of machine-dependent operations such as character manipulations, DATA statements, labeled COMMON, complex FORMAT specifications, and the like. In addition, each program has been run and debugged using OS/360 FORTRAN IV-H under MVY-HASP Release 19 on the APCO IBM/360-50 installed at the Research Triangle Park. The resulting programs should be as machine-independent as it is possible to make them. Nonetheless, slight variations in calculated numbers may arise due to machine-dependent characteristics such as internal work length, special system-supplied calculating subroutine, etc. These differences in results are expected to be much less than the limitations inherent in the input data.

Following the introduction, this volume is organized into three additional sections plus 24 appendices. Section II discusses the general procedures by which the individual programs are designed, and describes in detail the features which are generally shared by the source category programs, to include standard input and output routines. Section III describes the input to and output from the Stage 3 programs which produce the output summaries, growth estimates, and implementation schedules. Each of the Appendices A through U contain a detailed discussion of the operation of a source program, a description of the input parameters and data, a glossary of all of the FORTRAN names used in the program, and tables of the parameters used in calculating the costs and emissions. Appendix V describes the standard output for each plant processed by each source programmed. This subroutine is combined with other source results and used to prepare output summaries, growth estimates, and implementation schedules. Appendix W describes the output data from the source programs which are matched to correspond to the proper metropolitan area. Appendix X presents the assumed emission standards selected for this report and are representative of those now used throughout the Nation.

## II. GENERAL DESCRIPTION OF SOURCE CATEGORY PROGRAMS

### A. Introduction

The source category programs, because they involve calculating costs and emissions for very diverse types of emission sources, necessarily require diverse calculating and programming techniques. However, since the source programs are part of one overall system, they are designed to be as identical as possible with regard to input and output in order to simplify their use. This section of the report describes those areas of program design similarity. Any departures from the procedures described herein are noted and explained in the appropriate appendix.

### B. Types of Calculations Performed

All source category programs calculate investment and annual costs required for each source to reduce its emissions to the level required by the applicable standard. Six emissions, particulates, sulfur oxides, carbon monoxide, hydrocarbons, fluorides, and lead, are programmed to meet the assumed standards as presented in Appendix X.

A detailed discussion of the application of relevant standards to the various stationary sources is found in Volume I, Appendix IV. The standards applied in the computer program for each source are specified in the detailed write-up in the appropriate appendix of this report.

Emissions are calculated for Calendar Year 1967 resulting from then-existing sources and control equipment as determined from the data gathered or assumed from other information obtained. Also, emissions from the same sources are computed after additional required controls (if any) are installed.

Costs and emissions are calculated based on the best information available. In some cases, this information is far from "ideal" (i.e., with sufficient detail) to allow for accurate calculation of costs and emissions for a particular source. As a result, three general approaches were considered for inclusion in all source category programs (in order of increasing quality):

1. Where plant location only was known, calculation of nominal or average plant sizes was calculated and used as a parameter; in this case, each plant would show the same costs and emissions;
2. Where total plant or individual process capacity and plant location was known; in this case, a cost/unit capacity was calculated based on an average, industry-wide 1967 control level; and
3. Where plant data, including individual process size, type, number, and 1967 control level were known.

Each source category program was written to allow, without interval re-programming, use of data at the quality level available for this report plus data of the higher quality level(s), if any, as it becomes available. In fact, as better data becomes available, it can be used to gradually upgrade the data base for each source category program. Care should be exercised, however, since the mixing of two or more types of data can lead to estimates which are improperly biased--for example, substituting type 2 data for type 1 data for all large plants only.

In general, the value of input variable IAUX (Section C) specifies the type of data available for the plant identified on the card. However, another datum may occasionally be used, or none; details may be found in the appropriate appendix for the particular source program.

Actual computation procedures, and the input parameters required to produce cost and emission data, vary from program to program. The appropriate appendix should be consulted for details.

### C. Standard Input Data Format

Input data describing each plant are contained on standard 80-column punched cards of two types: (1) data for quality levels one and two can be contained on one card type one alone, and (2) data for quality level three requires, in addition, one or more cards of type two, as determined by NPROC.

Table 2 presents a description of each datum on card types one and two and card formats.

### D. Standard Output Data Format

Each source program has attached to it Subroutine OUTFI. This subroutine provides output that will later be used in the Emission and Implementation Report, and Table 3 presents the layout of the cards produced by this subroutine. One card is produced for each emission for each plant, and, therefore, a large number of cards or "card images" are produced for those sources that are comprised of a large number of plants. Since the cost of control equipment is for a complete plant, these data are put on the first emission card and all other emission cards have blanks in these fields.

These cards may be put directly into the report generator (card option of SEARCH) or stored on a master data file (FILE), as required.

## III. GENERAL DESCRIPTION OF THE REPORT GENERATOR

### A. Introduction

The report generator programs fall into three basic categories: (1) data base standardization (MATCH), (2) file maintenance (FILE), and (3) output display (SEARCH and PRINT). These programs provide a

TABLE 2. - STANDARD INPUT DATA CARDS

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card Type 1 | | |
| | Blank | 1 | 1X |
| * | Card Number | 2 | 1 |
| * | Auxiliary Code | 3 | I1 |
| * | Source | 4-5 | I2 |
| * | RSAC Code (plus part code) | 6-10 | A4, A1 |
| * | Total Capacity | 11-20 | F10.0 |
| * | Number of Processes | 21-22 | I2 |
| * | Data Input Number One | 23-26 | For I4 |
| * | Data Input Number Two | 27-30 | For I4 |
| * | Name and Address or Notes | 31-78 | as req. |
| | Blank | 79-80 | 2X |
| | Card Type 2 | | |
| | Blank | 1 | 1X |
| * | Card Number | 2 | 2 |
| * | Auxiliary Code | 3 | I1 |
| * | Source | 4-5 | I2 |
| * | RSAC Code | 6-10 | A4, A1 |
| * | Process Type | 11-12 | I2 |
| * | Number of Units | 13-15 | For I3 |
| * | Control Efficiency | 16-17 | For I2 |
| * | Unit Process Size | 18-25 | For I8 |
| | Blank | 26-30 | 5X |
| * | Process Type | 31-32 | I2 |
| * | Number of Units | 33-35 | For I3 |
| * | Control Efficiency | 36-37 | For I2 |
| * | Unit Process Size | 38-45 | For I8 |
| | Blank | 46-50 | 5X |
| * | Process Type | 51-52 | I2 |
| * | Number of Units | 53-55 | For I3 |
| * | Control Efficiency | 56-57 | For I2 |
| * | Unit Process Size | 57-65 | For I8 |
| | Blank | 66-80 | 15X |

* FORTRAN variable specific to each source program.

TABLE 3. - DATA CONTAINED ON SOURCE OUTPUT CARDS (SUBROUTINE OUTFI)

| Definition | Card Columns | FORTRAN Format |
|---|---|---|
| Blank | 1 | 1X |
| RSAC Code | 2-5 | A4 |
| RSAC Part Code (usually blank) | 6 | A1 |
| Source Code | 7-8 | I2 |
| Pollutant Code | 9 | I1 |
| Metropolitan Area (AQCR) Code | 10-12 | A3 |
| Investment Costs (thousands of dollars) | 13-23 | F11.2 |
| Annual Costs (thousands of dollars per year) | 24-34 | F11.2 |
| Present Emissions (tons/year) | 35-45 | F11.2 |
| Controlled Emissions (tons/year) | 46-56 | F11.2 |
| Plant Name, etc. | 57-80 | 6A4 |

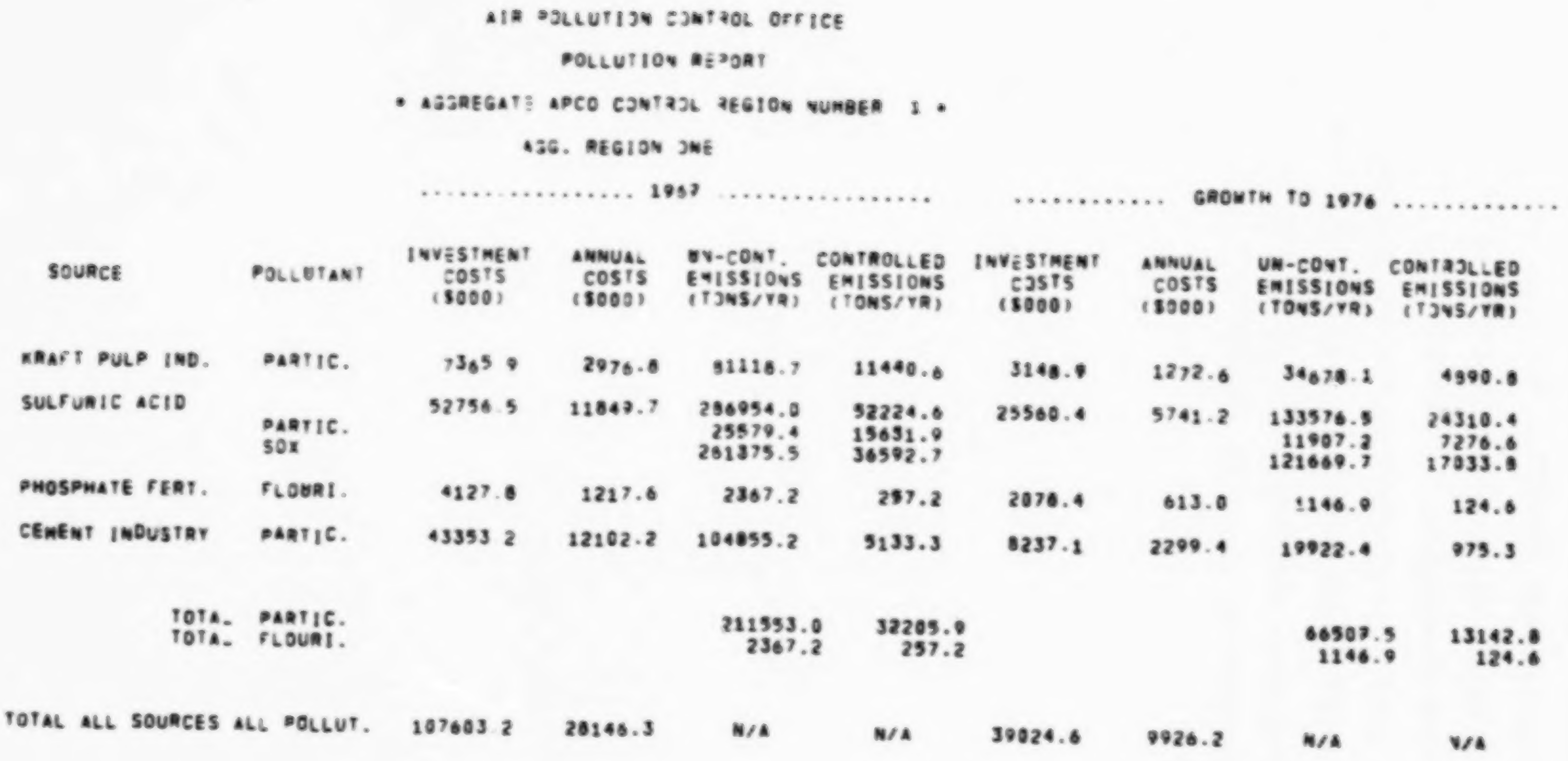
way of storing, accumualting, and displaying the results of the individual source programs.

B. Report Generator Programs

Program MATCH provides a metropolitan area (AQCR) if the RSAC is known, and provides a state RSAC when only the metropolitan area is known. This latter process is necessary when a state summary is desired. The input is taken directly from cards produced by OUTFI and the output cards are the same except for the inserted code.

Program FILE is used to create or update a file of all output cards (from OUTFI and if necessary processed through MATCH). The update capability is provided by a series of control cards that allow for the replacement of cards on a data file, deletion of certain data cards, or insertion of data cards. An updated list of the data file is also provided, if required.

Programs SEARCH and PRINT provide for collecting the data into the geographical area desired (SEARCH) and displaying pollution summaries and possible implementation schemes (PRINT). The data may be displayed by individual metropolitan area, state, aggregate metropolitan area (variable makeup, up to nine groupings), and nationwide. The printout may be source by source, pollutant breakdowns within sources, and/or implementation estimates and effectiveness over a variable number of years. A typical aggregate area printout is shown in Figure 1 and a typical implementation printout is shown in Figure 2.



```
                            AIR POLLUTION CONTROL OFFICE

                                 POLLUTION REPORT

                      * AGGREGATE APCO CONTROL REGION NUMBER  1 *

                                  AGG. REGION ONE

                     ................. 1967 ..................      ............ GROWTH TO 1976 ............

   SOURCE            POLLUTANT   INVESTMENT   ANNUAL     UN-CONT.   CONTROLLED  INVESTMENT   ANNUAL    UN-CONT.   CONTROLLED
                                   COSTS       COSTS    EMISSIONS   EMISSIONS     COSTS       COSTS   EMISSIONS   EMISSIONS
                                  ($000)      ($000)    (TONS/YR)   (TONS/YR)    ($000)      ($000)   (TONS/YR)   (TONS/YR)

KRAFT PULP IND.      PARTIC.       7365.9     2976.8     81118.7     11440.6     3148.9      1272.6    34678.1      4990.8

SULFURIC ACID                     52756.5    11849.7    286954.0     52224.6    25560.4      5741.2   133576.5     24310.4
                     PARTIC.                             25579.4     15631.9                           11907.2      7276.6
                     SOX                                261375.5     36592.7                          121669.7     17033.8

PHOSPHATE FERT.      FLOURI.       4127.8     1217.6      2367.2       257.2     2078.4       613.0     1146.9       124.6

CEMENT INDUSTRY      PARTIC.      43353.2    12102.2    104855.2      5133.3     8237.1      2299.4    19922.4       975.3


            TOTAL    PARTIC.                            211553.0     32205.9                           66507.5     13142.8
            TOTAL    FLOURI.                              2367.2       257.2                            1146.9       124.6


TOTAL ALL SOURCES ALL POLLUT.    107603.2    28146.3        N/A         N/A     39024.6      9926.2       N/A         N/A
```

Fig. 1. Typical Aggregate APCO Control Area Printout.

```
                         AIR POLLUTION CONTROL OFFICE
                               POLLUTION REPORT
                    * AGGREGATE APCO CONTROL REGION NUMBER  1 *
                               AGG. REGION ONE

       SOURCE- KRAFT PULP IND.


                  .......... ........ IMPLEMENTATION ..................
                  FULL IMPLEMENTATION                      FIFTY PERCENT          ( .50 )

 YEAR     INV COSTS    ANNUAL COSTS  POLLUTANT LEVEL     INV COSTS    ANNUAL COSTS  POLLUTANT LEVEL
           ($000)        ($000)       (TONS/YR)           ($000)        ($000)       (TONS/YR)
                                                                                              (1967 BASE)
 1971      1227.7         496.1        69505.7             613.3         248.1        75312.2
 1972      1227.7         992.3        57892.7             613.3         496.1        69505.7
 1973      1227.7        1488.4        46279.7             613.3         744.2        63699.2
 1974      1227.7        1984.5        34666.7             613.3         992.3        57892.7
 1975      1227.7        2480.7        23053.7             613.3        1240.3        52086.2
 1976      1227.7        2976.8        11440.8             613.3        1488.4        46279.7

 TOTAL     7365.9        2976.8        11440.8            3682.9        1488.4        46279.7
                                                                                              (GROWTH)
 1971       524.8         212.1        29713.6             262.4         106.0        32195.8
 1972       524.8         424.2        24749.0             262.4         212.1        29713.5
 1973       524.8         636.3        19784.4             262.4         318.1        27231.2
 1974       524.8         848.4        14819.9             262.4         424.2        24748.9
 1975       524.8        1060.5         9855.4             262.4         530.2        22266.6
 1976       524.8        1272.6         4890.8             262.4         636.3        19784.2

 TOTAL     3148.9        1272.6         4890.8            1574.5         636.3        19784.2
```

Fig. 2. Typical Implementation Printout.

# APPENDIX A

## Computer Program for Solid Waste

# Appendix A

## Computer Program for Solid Waste

### I. INTRODUCTION

The amount of solid waste generated through households, industries, and other commercial activities was approximately 10.2 pounds per capita in 1967. The methods used to dispose of this waste matter cause significant amounts of particulates, carbon monoxide, and hydrocarbons to be generated.

The purpose of this report is to describe a computer program designed to compute the emissions and costs for controlling the emissions due to solid waste disposal. A general flow diagram of the computer logic is shown in Figure A-1.

Section II of this report gives some of the major assumptions and limitations of the computer program. Section III explains the program logic. Section IV is a glossary of FORTRAN names used in the program, and Section V is a listing of the computer program.

### II. MAJOR ASSUMPTIONS

The major assumptions made in regard to the calculations of emissions and control costs for solid waste are as follows:

a) The amount of refuse collected is assumed to be 5.5 pounds per capita per day.

b) The amount of uncollected refuse is assumed to be 4.7 pounds per capita per day.

c) Thirty-three percent of the collected refuse, which is not incinerated, is disposed of by open burning and the remainder by land filling.

d) Twenty-five percent of the uncollected refuse is disposed of by open burning, 25 percent by incinerating, and the remainder by land filling.

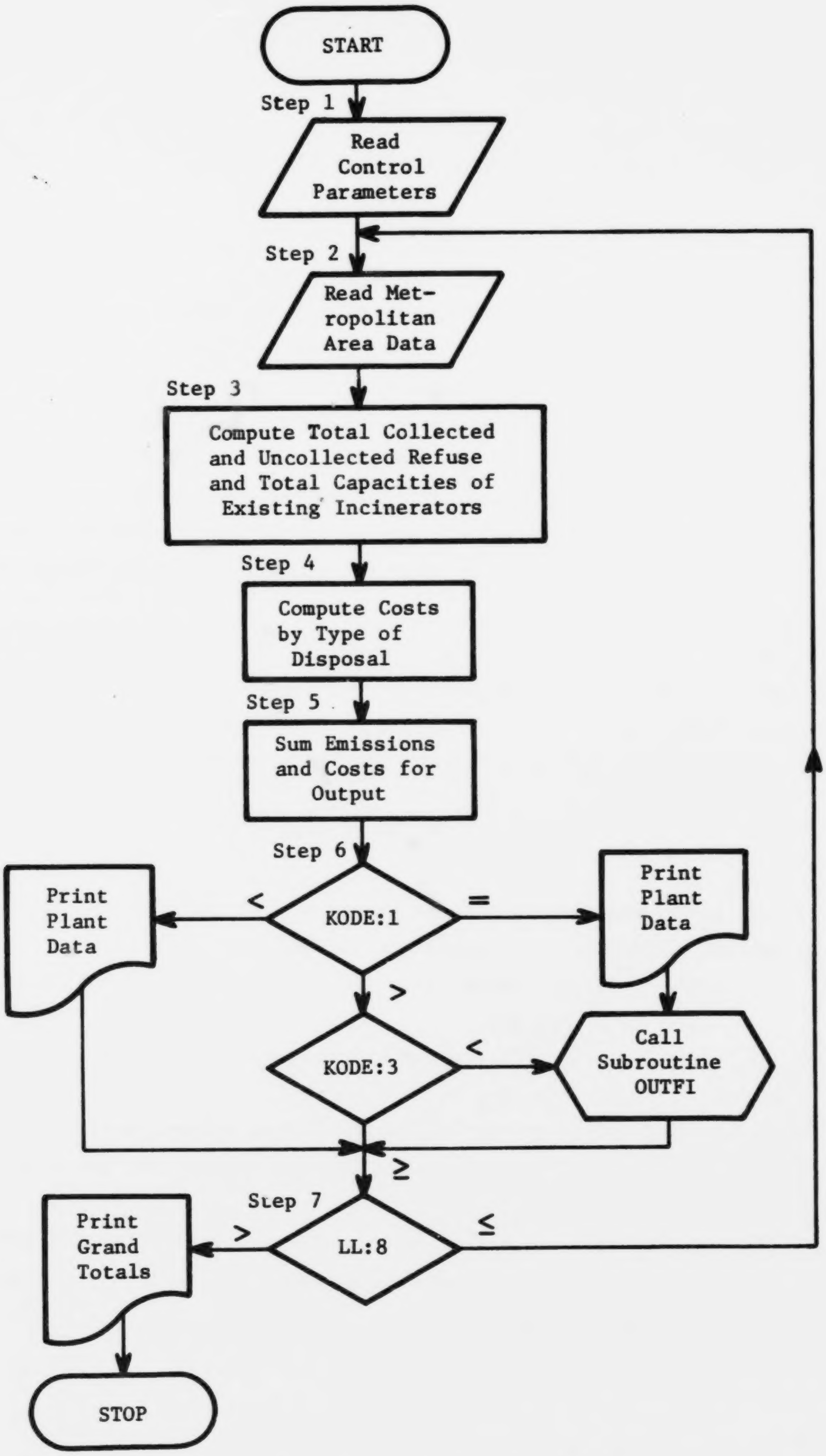

START
Step 1
Read Control Parameters
Step 2
Read Metropolitan Area Data
Step 3
Compute Total Collected and Uncollected Refuse and Total Capacities of Existing Incinerators
Step 4
Compute Costs by Type of Disposal
Step 5
Sum Emissions and Costs for Output
Step 6
KODE:1
<
=
>
Print Plant Data
Print Plant Data
KODE:3
<
Call Subroutine OUTFI
≥
Step 7
LL:8
>
≤
Print Grand Totals
STOP

Fig. A-1. Flow Chart of Computer Program for Solid Waste

e) The metropolitan areas which have no municipal incinerators will convert all open burning to sanitary landfills; i.e., no new incinerators will be built for air pollution control purposes.

f) Twenty percent of the smaller incinerators used to dispose of uncollected refuse will be abandoned in favor of landfill at no added costs and another 20 percent already meet the required emission control regulations.

g) The per capita generation of solid waste will increase at a rate of 3 percent per year.

## III. PROGRAM LOGIC

The logic employed in this computer program assumes an ideal data base consisting primarily of population and existing methods of solid waste disposal. Following are the step by step processes of the computer program.

Step 1.

Four data cards as shown in Table A-1 contain control parameters and cost factors which are constant throughout the program. KPOP determines the population option as explained in Table A-1 and the purpose for KODE is explained in Step 6.

The cost factors, CFA1(I), and CFA2(I), are for investments and annual costs, respectively, where I equals "1" for incinerators built before 1961, "2" for units built between 1961 and 1964, and "3" for units built after 1964.

Step 2.

The input data for each of the 298 metropolitan areas consist of population and incinerator data for all counties or municipalities in the metropolitan area shown in Table A-2. There are three types of input cards. Card type number 1 gives the metropolitan area number, the number of counties or municipalities in the area, and the area name. Following this card type are the type 2 data cards with RSAC codes, number of incinerators if any in each metropolitan area, population data, and name of the metropolitan area. If there are incinerators

TABLE A-1. - CONTROL PARAMETERS FOR THE SOLID WASTE PROGRAM

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Format for Card 1 | | |
| KPOP | The population option to use is denoted by a "1" for 1967, a "2" for 1970, and a "3" for 1975. | 1-5 | I5 |
| KODE | Denotes when to print plant data and when to bypass Subroutine OUTFI. | 6-10 | I5 |
| | Format for Card 2 | | |
| PC | The number of pounds of refuse per capita per day collected. | 1-10 | F10.2 |
| PV | The number of pounds of refuse per capita per day uncollected | 11-20 | F10.2 |
| | Format for Cards 3 and 4 | | |
| CFA1(I), I=1,3 | Investment cost to upgrade existing municipal incinerators according to year built. | 1-30 | 3F10.0 |
| CFA2(I), I=1,3 | Annual operating costs to upgrade existing municipal incinerators according to year built. | 1-30 | 3F10.0 |

TABLE A-2. - METROPOLITAN AREA DATA FOR THE SOLID WASTE PROGRAM

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Format for Card 1 | | |
| NOC | Number of card. | 1-2 | I2 |
| NREG | Metropolitan area number assigned arbitrarily in sequential order. | 3-5 | I3 |
| IC | Dummy parameter used to check for card type. Should be blank for this card. | 6-9 | I4 |
| NTC | Number of counties in metropolitan area. | 10-12 | I3 |
| | Blank | 13-40 | 28X |
| IREG(I), I=1,8 | Metropolitan area name. | 41-72 | 8A4 |
| | Format for Card 2 | | |
| NOC | Number of card. | 1-2 | I2 |
| NREG | Metropolitan area number same as record S. | 3-5 | I3 |
| RSAC | National location code. | 6-9 | A4 |
| NOING | Number of incinerators in each county or municipality in each metropolitan area. | 10-13 | I4 |
| POP1 | 1967 population in thousands. | 14-22 | F9.2 |
| POP2 | 1970 population in thousands. | 23-31 | F9.2 |
| POP3 | 1975 population in thousands. | 32-40 | F9.2 |
| IREG(I), I=1,8 | County or municipality name. | 41-72 | 8A4 |
| | Format for Card 3* | | |
| | Blank | 1-10 | 10X |
| YR(I) | Year incinerator I was installed. | 11-16 | F6.0 |
| CAP(I) | Capacity of incinerator I, (tons/day). | 17-26 | F10.0 |
| | Blank | 27-30 | |
| YR(I+1) | Year incinerator I+1 was installed. | 31-36 | F6.0 |
| CAP(I+1) | Capacity of incinerator I+1 (tons/day). | 37-46 | F10.0 |
| | Blank | 47-50 | 4X |
| YR(I+2) | Year incinerator I+2 was installed. | 51-56 | F6.0 |
| CAP(I+2) | Capacity of incinerator I+2 (tons/day). | 57-66 | F10.0 |
| | Blank | 67-80 | 14X |

* I is equal to 1 to NOINC and the number of cards with this format are dependent on that number with up to 3 per card.

in the area, a card or cards containing the RSAC code and up to 3 data fields containing year of installation and capacities are read into the program.

Step 3.

The total refuse collected, TOTC (tons/day), is computed by multiplying the designated population by PC which was an input on card 2 of the control parameters. The uncollected, TOTUC, is computed the same way but with the factor, PV, as input on card 2.

The total number of incinerators, NINC(I), for the I-th year group, and their respective capacities CAPI(I) are summed. The waste disposal is then computed by process type, PROC(I), when I is "1" for incinerated refuse, "2" for open burned, and "3" for land fill. The amount of refuse disposed of by PROC(1) is equal to the total capacity of all incinerators. PROC(2) is 33 percent of the collected refuse which is not incinerated, and PROC(3) is the balance of the collected refuse. The uncontrolled refuse is disposed of with 25 percent incinerated, 25 percent open burned, and 50 percent land fill.

Step 4.

The investment and annualized costs for upgrading existing municipal incinerators are computed as follows:

$$C_1 = \sum_{i=1}^{i=3} CFA1_i \times CAPI_i \text{ ; and}$$

$$AC1 = \sum_{i=1}^{i=3} CFA2_i \times CAPI_i \, .$$

$CFA1_i$ and $CFA2_i$ are input data as explained in Step 1, and $CAPI_i$ is computed in Step 3.

The costs, C2, to construct new incinerators with capacity S, tons/day, which will replace 25 percent of open burning is computed as follows:

$S = 0.25 \times 0.33 \times DIFF$, where

DIFF is the total collected refuse which is not incinerated.

If S is greater than 300

$C2 = 5600 \times S$ .

If S is less than or equal to 300

$C2 = 7500 \times S$ .

$AC2 = 1800 \times S$ .

The cost, C3, to upgrade existing small incinerators is computed as:

$$C3 = 0.25 \times TOTUC \times 1000 \times 0.60 \ .$$

The cost for operating a sanitary landfill in place of 75 percent of municipal open burning dumps is computed as:

$$AC3 = \frac{S}{0.25} \times 0.30 \times 360 \ .$$

The cost for operating a sanitary landfill in place of 25 percent of the smaller incinerators is computed as:

$$AC4 = 0.25 \times TOTUC \times 0.40 \times 360.$$

The annualized costs for existing small incinerators is computed as:

$$AC5 = 0.25 \times TOTUC \times 0.60 \times 259.$$

In metropolitan areas with no existing municipal incinerators, S is zero and C3 is the only investment cost.

The total investment and annualized costs ($1000) are computed as:

$$COST1(1) = \frac{C1 + C2 + C3}{1000.} \text{ ; and}$$

$$COST1(2) = \frac{AC1 + AC2 + AC3 + AC4 + AC5}{1000.0} \ .$$

The 1967 emissions are then computed as follows:

Particulates

$$EM1_1 = 3.1 \ [CAPI_1 + CAPI_2] + 0.9 \ CAPI_3 + 3.05 \left[\frac{S}{0.25}\right] + 1.23 \ TOTUC$$

Hydrocarbons

$$EM3_1 = 0.275 \ CAPIN + 5.4 \left[\frac{S}{0.25}\right] + 1.78 \ TOTUC$$

Carbon Monoxides

$$EM4_1 = 0.183 \ CAPIN + 15.5 \left[\frac{S}{0.25}\right] + 4.58 \ TOTUC$$

The emissions of particulates after controls are dependent on the sizes of the incinerators and are computed as follows:

$PIC = 0.73\ CAP_i$ for incinerators with capacity less than 400 tons/day.

$PIC = 0.55\ CAP_i$ for incinerators with capacity greater than 400 tons/day.

Emissions from uncollected refuse and new incinerators are:

$P3C = 0.18\ TOTUC$ ; and

$P4C = 0.6\ S$.

Total particulate emissions after control are:

$EM1_2 = PIC + P3C + P4C$.

Controlled hydrocarbon and carbon monoxide emissions are computed as:

$EM3_2 = 0.275\ CAPIN + 0.46\ TOTUC + 0.275S$, and

$EM4_2 = 0.183\ CAPIN + 0.70\ TOTUC + 0.183S$.

Step 5.

A summation (SUM(I)) of all emissions and costs are kept in order to print out totals for each metropolitan area. At the end the totals for each area are summed (TOT(I)) in order to output grand totals for any number of metropolitan areas.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

Step 7.

The program checks the first metropolitan area data card, which is inserted at the end of real data, for an "8" or a "9" punched in NOC (Column 2). If the value for NOC is "8," the program prints out TOT(I) and returns control to Step 3 where the process is resumed with subsequent metropolitan areas until a "9" appears in the "NOC" column. When the value for NOC is "9," the program prints the grand totals and terminates.

## IV. GLOSSARY OF FORTRAN NAMES FOR THE SOLID WASTE PROGRAM

| FORTRAN Name | Definition |
|---|---|
| AC1 | Annual control costs for existing municipal incinerators. |
| AC2 | Annual control costs for new incinerator. |
| AC3 | Annual operating cost for operating a sanitary landfill in place of 75 percent of municipal open burning dumps. |
| AC4 | Annual operating cost for operating a sanitary landfill in place of 25 percent of the smaller incinerators. |
| AC5 | Annual operating cost for existing small incinerators. |
| CAP(20) | Capacity of incinerator I when I is 1 to NOINC. |
| CAPI(3) | Capacities of all incinerators in I-th year group. |
| CAPIN | Total capacity of all municipal incinerators. |
| CFA1(3) | Investment cost factor for upgrading existing municipal incinerators for the I-th year group. |
| CFA2(3) | Annual cost factor for upgrading existing municipal incinerators for the I-th year group. |
| COST1(2) | Investment and annual operating costs, $1000. |
| C1 | Investment costs for upgrading existing municipal incinerators. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| C2 | Investment cost for constructing new municipal incinerators. |
| C3 | Investment cost to upgrade existing small incinerators. |
| DIFF | The amount of the collected refuse less the total capacities of all incinerators. |
| EM1(2) | Particulate emissions before and after controls. |
| EM3(2) | Hydrocarbon emissions before and after controls. |
| EM4(2) | Carbon monoxide emissions before and after controls. |
| IC | Input parameter for checking validity of metropolitan area data card. |
| INP(8) | Name of county or municipality. |
| IREG(8) | Name of metropolitan area. |
| JE1 | Numerical value assigned to first pollutant for source. Used in calling parameters for OUTFI. |
| JE3 | Numerical value assigned to second pollutant for source. Used in calling parameters for OUTFI. |
| JE4 | Numerical value assigned to third pollutant for source. Used in calling parameters for OUTFI. |
| KODE | Input value to denote when to bypass Subroutine OUTFI and/or the printouts of individual metropolitan area data. |
| KPOP | Input value to denote which population base to use. |
| NE | Number of pollutants from source. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| NINC(3) | Number of incinerators in J-th year group. |
| NOC | Card number and/or type. |
| NOINC | Total number of incinerators in county or municipality. |
| NREG | Numerical value assigned to metropolitan area (1-298). |
| NS | Numerical value assigned to source. |
| NTC | Number of counties and/or municipalities in metropolitan area. |
| PC | Amount of collected refuse in pounds per capita per day. |
| PIC | Controlled particulates, tons/yr. from incinerators greater than 400 tons per year. |
| POP | Population of county or municipality. |
| POP1 | 1967 population of county or municipality. |
| POP2 | 1970 population of county or municipality. |
| POP3 | 1975 population of county or municipality. |
| PROC(3) | Amount of collected refuse disposed of by process type I. |
| PROCU(3) | Amount of uncollected refuse disposed of by process type I. |
| PV | Amount of uncollected refuse in pounds per capita per day. |
| P3C | Controlled particulates, tons/yr., from uncollected refuse. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| P4C | Controlled particulates, tons/yr., from new incinerators. |
| RSAC | National location code. |
| S | Amount of collected refuse, tons/day, which will replace 25 percent of open burning. |
| SUM(8) | Total emissions and costs for a metropolitan area. |
| TOT(8) | Total emissions and costs for any specified number of metropolitan areas. |
| TOTC | Total collected refuse, tons/day. |
| TOTCAP | The selected population determined by the input parameter, KPOP. |
| TOTUC | Total uncollected refuse, tons/day. |
| YR(20) | Year the I-th municipal incinerator was built. |

# V. LISTING FOR COMPUTER PROGRAM SWAT

```
C      PROGRAM SWAT
C         PROGRAM TO COMPUTE EMISSIONS AND COSTS OF CONTROL FOR
C      SOLID WASTES
C         EMISSIONS FROM SOLID WASTES ARE PARTICULATES,HYDROCARBONS, AND
C         CARBON MONOXIDES.
C
      INTEGER RSAC
      DIMENSION IREG(8)
      DIMENSION INP(12),YR(20),CAP(20),PROC(4),NINC(10),PROCU(4),EM1(2),
     2EM3(2),EM4(2),COST1(2), CFA1(3),CFA2(3), SUM(12),CAPI(3),TOT(8)
      JE1 = 1
      JE3 = 3
      JE4 = 4
      NS = 1
      NE = 3
C         READ IN CONTROL CARD TO DETERMINE WHICH POPULATION OPTION TO
C         USE AND IF SUBROUTINE OUTFI IS REQUIRED..
C           KPOP IS 1 FOR 1967 POPULATION, 2 FOR 1970, AND 3 FOR 1975.
C
      READ 360, KPOP,KODE
C         READ IN AMOUNT OF REFUSE (LBS/CAPITA/DAY) COLLECTED (PC) AND
C         UNCOLLECTED (PU).
      READ 395, PC,PU
      READ 840,(CFA1(I),I=1,3 )
      READ 840,(CFA2(I),I=1,3 )
    1 CONTINUE
      DO 2 I = 1,8
 2    TOT(I) = 0.
      PRINT 398
      PRINT 399
      PRINT 400
 10   CONTINUE
      DO 4 K = 1,8
      TOT(K) = TOT(K) + SUM(K)
 4    SUM(K) = 0.
      READ 850, NOC,NREG,IC,NTC,(IREG(I),I=1,8)
      IF(NOC-8) 18,809,810
 18   CONTINUE
      IF(IC)5,11,5
 5    PRINT 6
 6    FORMAT (30H  READ IN WRONG CARD FOR AQCR )
      GO TO 10
 11   CONTINUE
      PRINT 401, NREG,NTC,(IREG(I),I=1,8)
 401  FORMAT (I5,I5,13H COUNTIES IN ,8A4)
      DO 800 ICK= 1,NTC
      READ 851, NOC,NREG,RSAC,NOINC,POP1,POP2,POP3,(INP(I),I=1,8)
 851  FORMAT (I2,I3,A4,I4,3F9.2,8A4)
      IF(KPOP-2)12,13,14
 12   TOTCAP = POP1
      GO TO 15
 13   TOTCAP = POP2
      GO TO 15
 14   TOTCAP = POP3
 15    CONTINUE
       DO 8 J = 1,3
       NINC(J) = 0
       PROC(J) = 0
 8     CAPI(J) = 0.
       IF(NOINC)30,30,19
 19    CONTINUE
       I = 1
 20    CONTINUE
       READ 510, YR(I),CAP(I),YR(I+1),CAP(I+1),YR(I+2),CAP(I+2)
 510   FORMAT (10X,F6.0,F10.0,4X,F6.0,F10.0,4X,F6.0,F10.0,14X)
       IF(NOINC-(I+2))30,30,21
 21    I = I+3
       GO TO 20
 30    CONTINUE
       POP = TOTCAP * 1000.
C         TOTCAP IS THE POPULATION
C         NOINC IS THE NUMBER OF INCINERATORS
C         CAP(I) IS THE FURNACE CAPACITY, TONS/DAY
C
       PROC(I) = 0.
C         COMPUTE THE REFUSE COLLECTED ( TOTC AT 5.3 LBS/CAPITA AND THE
C      UNCOLLECTED (TOTUC) AT 4.7 LBS/CAPITA IN TONS/DAY
       TOTC =(POP * PC )/2000.0
       TOTUC = (POP * PU )/2000.0
       DIFF = 0.
C         COMPUTE THE TONS/DAY DISPOSED OF BY PROCESS TYPES (PROC(IR,I)),
C            FOR COLLECTED REFUSE AND PROCU(IR,I) FOR UNCOLLECTED REFUSE,
C            WHERE I = 1 FOR INCINERATED REFUSE
C                  I = 2 FOR OPEN BURNED REFUSE
C
C         SUM THE NUMBER OF INCINERATORS IN EACH YEAR GROUP (NINC(IR,J)
C           WHERE J = 1 IF CONSTRUCTED PRIOR TO 1961
C                     2 IF 1961 - 1964
C                     3 IF 1965 - 1967
C           AND THE DAILY CAPACITY, CAPI(IR,J), T/D  FOR EACH YEAR GROUP.
       CAPIN = 0.
       IF(NOINC)36,36,38
 36    DIFF = TOTC
       CAPIN = 0.
       PROC(1) = 0.
       GO TO 102
 38    CONTINUE
       DO 90 I = 1,NOINC
       CAPIN = CAP(I) + CAPIN
       IF (YR(I)- 1961.)40,50,50
 40    J = 1
       GO TO 80
 50    CONTINUE
       IF (YR(I)-1964.)60,60,70
 60    J = 2
       GO TO 80
 70    J = 3
 80    NINC(J) = NINC(J) + 1
       CAPI(J) = CAPI(J)+ CAP(I)
 90    CONTINUE
       DIFF = TOTC - CAPIN
       IF(DIFF)110,110,100
 100   PROC(1) = CAPIN
```

```
  102 PROC(2) =            0.75 * DIFF
      PROCU(1)=            0.25 * TOTUC
      PROCU(2)=            0.25 * TOTUC
      GO TO 120
  110 PROC(1) =  TOTC
      PROCU(1)=            0.25 * TOTUC
      PROCU(2)=            0.25 * TOTUC
      DIFF = 0.
  120 CONTINUE
      PROCU(3)=            0.50 * TOTUC
C         CALCULATE INVESTMENT COSTS
C            CAPIN IS TOTAL CAPACITY OF EXISTING INCINERATORS
      S = DIFF * 0.0825
      C1 = 0.
      C2 = 0.
      C3 = 0.
      AC1 = 0.
      AC2 = 0.
      AC3 = 0.
      AC4 = 0.
      AC5 = 0.
      PIC = 0.
      IF(CAPIN)200,240,200
  200 CONTINUE
      DO 210 J = 1,3
      C1 = C1 + CFA1(J) * CAPI(J)
  210 AC1 = AC1 + CFA2(J) * CAPI(J)
      AC2 = 1800.0 * S
      IF(S-300.)230,230,220
  220 C2 = 5600.0 * S
      GO TO 240
  230 C2 = 7500.0 * S
  240 CONTINUE
      C3 = 0.25 * TOTUC * 1000.0 * 0.60
      AC3 = (S/0.25) * 0.30 * 360.0
      AC4 = 0.25 * TOTUC * 0.40 * 360.0
      AC5 = 0.25 * TOTUC * 0.60 * 259.0
      COST1(1) = (C1 + C2 + C3)/1000.0
      COST1(2)=(AC1 + AC2 + AC3 + AC4 + AC5) / 1000.0
C         1967 EMISSIONS
      EM1(1) = 3.1 * (CAPI(1)+CAPI(2))+ 0.9 * CAPI(3)+ 3.05*(S/.25)+
     2 TOTUC * 1.23
      EM3(1) = 0.275 * CAPIN   + 5.4 *(S/0.25)+1.78* TOTUC
      EM4(1) = 0.183 * CAPIN   +15.5 * (S/.25)+4.58* TOTUC
C         COMPUTE CONTROLLED EMISSIONS
C
      IF(CAPIN) 190,190,160
  160 DO 190 I = 1,NOINC
      IF(CAP(I)-400.0)170,170,180
  170 PIC = PIC + 0.73 *CAP(I)
      GO TO 190
  180 PIC = PIC + 0.55 * CAP(I)
  190 CONTINUE
      P4C =  0.6 * S
      P3C = 0.18 * TOTUC
      EM1(2) = PIC + P3C +P4C
      EM3(2) = 0.275 * CAPIN   +0.46* TOTUC +0.275 * S
      EM4(2) = 0.183 * CAPIN   +0.70* TOTUC +0.183 * S
      PRINT 407, EM1(1),EM1(2),EM3(1),EM3(2),EM4(1),EM4(2),COST1(1),COST
     21(2),RSAC,NOINC
407  FORMAT (5X,8F12.3,2X,A4,I4)
      SUM(1) = SUM(1) + EM1(1)
      SUM(2) = SUM(2) + EM1(2)
      SUM(3) = SUM(3) + EM3(1)
      SUM(4) = SUM(4) + EM3(2)
      SUM(5) = SUM(5) + EM4(1)
      SUM(6) = SUM(6) + EM4(2)
      SUM(7) = SUM(7) + COST1(1)
      SUM(8) = SUM(8) + COST1(2)
      K = 0
      KX = 0
      IF(KODE)250,250,800
250   CONTINUE
      CALL OUTFI(RSAC,K,KX,NS,INP,COST1,NE,JE1,EM1,JE3,EM3,JE4,EM4)
800   CONTINUE
      PRINT 402, (SUM(N),N = 1,8)
402   FORMAT (5X,8F12.3)
      GO TO 10
 809  PRINT 412,(TOT(I),I=1,8)
412   FORMAT (//,2X,8F12.0)
      IF(KODE)820,820,1
820   CONTINUE
      WRITE OUTPUT TAPE 6,1001
1001  FORMAT(4H8888,76X)
      GO TO 1
810   CONTINUE
      PRINT 412, (TOT(I),I = 1,8)
      IF(KODE)821,821,822
821   CONTINUE
      WRITE OUTPUT TAPE 6,1002
1002  FORMAT(4H9999,76X)
      ENDFILE 6
822   CONTINUE
      STOP
      END

      SUBROUTINE OUTFI    (NR1,NR2,NAQCR,
     1           NS,NAME,CO,NE,JE1,EM1,JE2,EM2,JE3,EM3,JE4,EM4)
      DIMENSION NAME(12),CO(2),EM1(2),EM2(2),EM3(2),EM4(2)
    1 CALL IDCONV(1,N,NS,JE1,ID1,ID2)
      WRITE OUTPUT TAPE 6,101,NR1,NR2,ID2,NAQCR,
     1                      CO(1),CO(2),EM1(1),EM1(2),(NAME(N),N=1,6)
  101 FORMAT(1X,A4,A1,A3,A3,2F11.2,2F11.2,6A4)
C
C     SETUP TO PUNCH ONLY PRESENT COSTS AND EMISSIONS
C
      IF(NE-1) 5,5,2
    2 CALL IDCONV(2,0,0,JE2,ID1,ID2)
      WRITE OUTPUT TAPE 6,102,NR1,NR2,ID2,NAQCR,
     1 EM2(1),EM2(2),(NAME(N),N=1,6)
  102 FORMAT(1X,A4,A1,A3,A3,22X,2F11.2,6A4)
      IF(NE-2) 5,5,3
    3 CALL IDCONV(2,0,0,JE3,ID1,ID2)
      WRITE OUTPUT TAPE 6,102,NR1,NR2,ID2,NAQCR,
     1 EM3(1),EM3(2),(NAME(N),N=1,6)
      IF(NE-3) 5,5,4
    4 CALL IDCONV(2,0,0,JE4,ID1,ID2)
      WRITE OUTPUT TAPE 6,102,NR1,NR2,ID2,NAQCR,
     1 EM4(1),EM4(2),(NAME(N),N=1,6)
    5 CONTINUE
      RETURN
      END

      SUBROUTINE IDCONV(NN,NR,NS,NP,I01,I02)
C
C     THIS SUBROUTINE CONVERTS REGION NO,SOURCE NO,AND POLUTANT NO TO
C                 AN  A6 (A4+A2) FORMAT FOR PRINTING
C
      GO TO(1,9),NN
    1 NNQ = NR / 10
      NNT = NS / 10
      NNS = NS - 10*NNT
    6 IF(NNS) 7,7,8
    7 NNS = 10
    8 CONTINUE
      NNS = NNS.SHFT.(-12)
      NNT = NNT.SHFT.(-18)
      NNU = NP.SHFT.(-6)
      I02 = NNS + NNT + NNU
      RETURN
    9 NNS = I02.AND.=77770000
      NNU = NP.SHFT.(-6)
      I02 = NNS+NNU
      RETURN
      END
```

INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS

```
   3    9
     5.50       4.70
     500.       400.       200.
     360.       330.       310.
```

# APPENDIX B

## Computer Program for Steam-Electric Power Plants

# Appendix B

## Computer Program for Steam-Electric Power Plants

## I. INTRODUCTION

The program to calculate control costs and associated emissions for steam-electric power plants is concerned only with those boilers burning (residual) fuel oil and/or coal. Control measures applied are concerned with reducing both particulate and sulfur oxide emissions.

The appendix describes a computer program designed to compute the emissions and costs for controlling the emissions from steam-electric power plants. Figure B-1 shows a flow diagram of the program logic.

The rest of this appendix contains a detailed statement of the assumptions underlying the program, Section II; a description of the actual program operations, Section III; a glossary of FORTRAN names, Section IV; and a complete program listing plus parameters used in producing the economic analysis figures, Section V.

## II. ASSUMPTIONS

The assumptions made with regard to calculating control costs and emissions for steam-electric power plants are as follows:

a) No costs or emissions computed for plants using 100 percent gas.

b) All plants using gas 90 percent or more of the time will switch the other fuels used to low-sulfur fuels.

c) Where necessary, all plants of 200 MW or less capacity will switch fuels to low-sulfur fuels.

d) Where necessary, all plants with a load factor less than 17 percent will switch fuels to low-sulfur fuels, regardless of size.

e) Control of particulates is now practiced uniformly at 86 percent.

f) Dolomite-injection/wet scrubbing results in 99 percent removal of particulates and 90 percent removal of sulfur oxides.

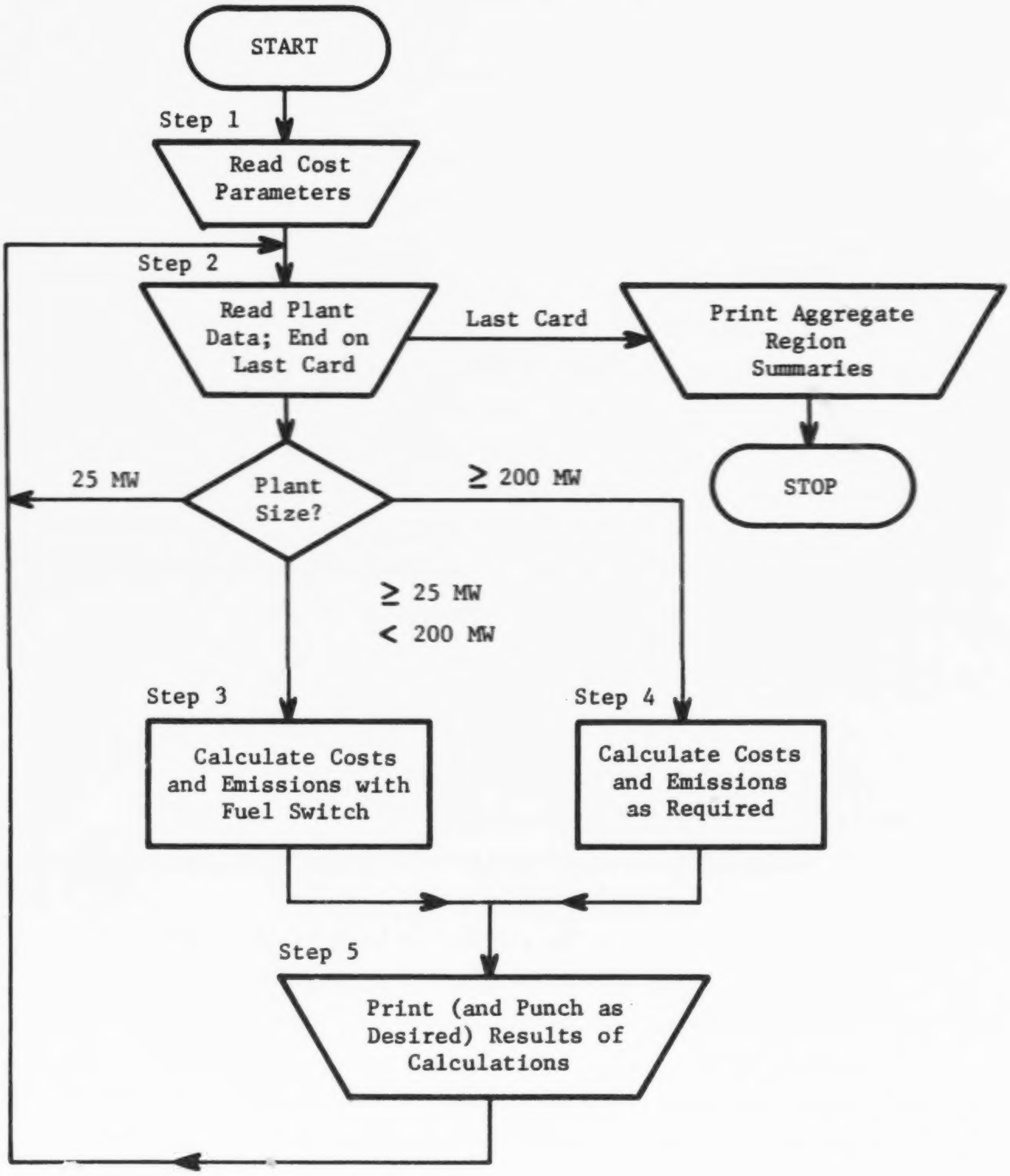

START
Step 1
Read Cost Parameters
Step 2
Read Plant Data; End on Last Card
Last Card
Print Aggregate Region Summaries
STOP
25 MW
Plant Size?
≥ 200 MW
≥ 25 MW
< 200 MW
Step 3
Calculate Costs and Emissions with Fuel Switch
Step 4
Calculate Costs and Emissions as Required
Step 5
Print (and Punch as Desired) Results of Calculations

Fig. B-1. - Flow Chart for the Steam-Electric Computer Program. .

g) Particulate control above 86 percent is not required on plants of 200 MW or less capacity.

h) No costs will be assigned to plants currently using 100 percent low-sulfur fuels, regardless of capacity, or plants using fuels which average to one percent or less sulfur coal on a B.t.u. basis.

Costs and emissions are based on the following:

a) Fuel premium costs of \$0.85/ton for cleaned coal and \$0.80/barrel for low-sulfur oil.

b) Cost equations for wet scrubbing and load factor corrections as supplied by APCO (see Table B-1).

c) Parameters for the cost equations (labor, material costs, etc.) as derived from TVA averages, except (d).

d) Annual capital charges of 20 percent.

e) Sulfur oxide levels achieved with coal that is one percent sulfur by weight giving $26 \times 10^6$ B.t.u./ton, and residual oil that is 1.38 percent sulfur by weight giving $6.1 \times 10^6$ B.t.u./barrel, for fuel switching.

f) Federal Power Commission reports of fuel sulfur contents, and other data on plants as supplied by APCO.

## III. PROGRAM LOGIC

Costs and emissions are calculated on a boiler-by-boiler basis, with output being given for each plant and for aggregate metropolitan areas (see output description). For this program, data are supplied which identify a plant as in metropolitan areas 1 - 40, metropolitan areas 41-298, outside metropolitan areas or unknown. This allows the source program to produce a simplified pollution report for immediate use.

Step 1.

Data for the premium cost of low-sulfur fuels, and for labor and materials costs associated with dolomite-injection/wet scrubbing are read in (see Table B-2 for details). Other program variables are initiated.

## TABLE B-1. - DOLOMITE-INJECTION/WET SCRUBBING COSTS

---

$$\text{Investment cost} = 10816.35(MW) - 4.584(MW)^2 + 934.19(S)(MW) - .396\,(S)(MW)^2$$

$$\begin{aligned}
\text{Annual cost} = {} & [\,+\,112.67(MW)(S) - 8.33(MW)]\,(L) + 1.3\,[.018(MW) + .595(S) \\
& + .0015(MW)(S) + 7.38]\,(M) + 1.2\,\Big[[.36\,(S)(MW)]\,(W) + [.0548(MW) - .00945(S) \\
& (MW) + .0020(MW)(S)^2]\,(K) + 322.57(MW) - .14376(MW)^2 + 29.46(MW)(S) - \\
& .01313(S)(MW)^2\Big] + [11.799(MW) - .00536(MW)^2]\,(T) + (\text{Investment Cost})(C)
\end{aligned}$$

where: MW = Megawatt rating of power plants

S = Sulfur content of fuel, as a percent

L = Limestone cost, \$/ton at 95 percent ($\mathrm{CalO_3}$ + MgO)

M = Cost of labor, \$/man-hr.

W = Cost of water, \$/$10^6$ gal.

K = Cost of electricity, \$/$10^6$ KWH

T = Cost of technical labor, \$/1000 man-hrs.

C = Annual capital charges as a percent of fixed investment, as a decimal

Base for estimate:

1) Existing power unit, 91 percent load.
2) Stack gas reheat to 250°F. by indirect liquid-gas method.
3) Direct solids disposal as 10 percent slurry at distance of one mile.
4) Two stage scrubbing.

Load factor corrections to annualized costs:

Coal: load factor $\geq$ 64 percent

Final annualized cost = [((91-load factor)x.00855xannual cost)+ annual cost] x (amount of coal used/(3000 x MW))

---

TABLE B-1. - DOLOMITE-INJECTION/WET SCRUBBING COSTS (continued)

---

33 percent $\leq$ load factor < 64 percent

Final annualized cost = [(1.23 +(64-load factor) x .0256) x annual cost]
x (amount of coal used/(3000 x MW)

17 percent $\leq$ load factor <33 percent

Final annualized cost = (2.0246 x annual cost + (32.9-load factor) x .0967 x annual cost) x (amount of coal used/(3000 x MW))

Residual fuel oil: load factor $\geq$ 64 percent

Final annualized cost = [((91-load factor) x .00855 x annual cost) + annual cost] x (amount of oil used/(12808 x MW))

33 percent $\leq$ load factor < 64 percent

Final annualized cost = ((1.2309 + (64-load factor) x .0256) x annual cost) x (amount of oil used/(12808 x MW))

17 percent $\leq$ load factor < 33 percent

Final annualized cost = (2.0246 x annual cost + (32.9-load factor) x .0967 x annual cost) x (amount of oil used/(12808 x MW))

---

Step 2.

Plant data are read in for one plant. With the exception of additional data on card types one and two, and a miximum of two groups of unit process data appearing on card type two, the input routine is identical to the standard (see Tables B-3 and B-4 for details).

Data were originally received from APCO on cards of two types--plant identification on one type and data for one boiler on each card of the second type. A third card type was added by RTI for each plant which gave coal ash content, coal and oil sulfur contents, and an aggregate metropolitan area number IREG. These three cards have been combined into two card types with identical boilers combined and all boilers for a plant arranged in decreasing order of size.

Step 3.

Plant capacity is checked. Plants of less than 25 MW are completely bypassed. Emissions and costs for fuel switching to low-sulfur fuels, where necessary, on a boiler-by-boiler basis are calculated for plants with less than 200 MW capacity. Subroutines FSWC and FSWO calculate costs for fuel switching to low-sulfur coal and oil, respectively. Subroutine CEM and OEM calculate the emissions.

Step 4.

For plants of capacity at 200 MW or more, each boiler group is checked for the fraction of natural gas used in its operation; boilers using gas only are bypassed. Boilers using 90 percent or more of gas or those with a load factor less than 17 percent have their nongas fuel switched to a low-sulfur type, if necessary, by using subroutine FSWC, FSWO, CEM, and/or OEM, as required (see Step 3).

Boilers which do not fall into the above categories are assigned dolomite-injection/wet scrubbing systems. Each group of identical boilers is assigned one scrubbing system, except as follows: (1) all boilers with a capacity of 25 MW or less are considered as requiring one control system, and (2) if any group of identical boilers has a capacity of over 1000 MW, its size is halved successively until the resultant nominal size is less than 1000 MW and the resulting costs are multiplied by the appropriate factor. Investment cost is calculated by subroutine INV, annual cost and all emissions by ANN.

If any group of boilers uses coal and oil, or a combination of the two, that meet the standard of 1 percent coal-equivalent sulfur on a B.t.u. basis, emissions only are calculated, using subroutine CEM and OEM.

Step 5.

When one plant is finished, the plant and location identification are printed with the total investment and annual costs, the 1967 and controlled emissions, and the original fuel sulfur contents for the plant. The same information (except for fuel sulfur data) may be punched with introduction of a suitable subroutine named OUTFI. The costs and emissions are then accumulated by aggregate region for final output. Control is returned to Step 2.

Step 6.

When a card with zero or blank for ICARD is read, final totals for the aggregate regions are printed out and the program stops.

TABLE B-2. - LIST OF PARAMETERS FOR STEAM-ELECTRIC PROGRAM

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| EFACT(4) | EFACT(1) and EFACT(2) are dummy variables. EFACT(3) contains premium cost of low-sulfur coal, in thousands of dollars per ton; EFACT(4) contains premium cost of low-sulfur oil, in thousands of dollars per barrel. | 1-32 | 4F8.0 |
| F(16) | F contains cost parameters for dolomite-injection/wet scrubbing in the following order: (1) limestone, in thousands of dollars per ton; (2) labor, in thousands of dollars/manhour; (3) water, in thousands of dollars/million gallons; (4) cost of electricity in thousands of dollars/million KWH; (5) cost of technical labor, in thousands of dollars/manhour; and (6) decimal fraction of investment cost charged annually to capitalization. | 33-80 | 6F8.0 |

TABLE B-3. - INPUT DATA DESCRIPTION FOR THE
STEAM-ELECTRIC PROGRAM

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1 and 2 | | |
| ICARD | Card identifier. | 1-2 | I1 |
| IAUX | Data type identifier. | 3 | I1 |
| ICODE | Source type identifier 102 for steam-electric. | 4-5 | I2 |
| IREG | Aggregate region number: 1 for metropolitan area 1-40; 2 for metropolitan area 41-298; 3 for non metropolitan area; 4 for unknown. | 6-9 | I4 |
| | Card 1 | | |
| NBOIL | Number of boiler groups in the plant. | 10-12 | I3 |
| DATA(1,3) | Plant capacity in MW. | 13-19 | F7.0 |
| ASH | Coal ash content for plant. | 20-22 | F3.0 |
| SCOAL | Coal sulfur content for plant. | 23-26 | F4.0 |
| SOI | Oil sulfur content for plant. | 27-30 | F4.0 |
| INPUT | Plant name and location. | 31-78 | 12A4 |
| | Card 2 | | |
| DATA(I,1) | Number of boilers in group. I with identical data. | 10-13,<br>41-44 | F4.0 |
| DATA(I,2) | Size of boilers in group I in MW. | 14-19,<br>45-50 | F6.0 |
| DATA(I,5) | Percent of coal fueling in group I. | 20-22,<br>51-53 | F3.0 |
| DATA(I,6) | Percent of oil fueling in group I. | 23-25,<br>54-56 | F3.0 |
| DATA(I,7) | Percent of gas fueling in group I. | 26-28,<br>57-59 | F3.0 |

### TABLE B-3. - INPUT DATA DESCRIPTION FOR THE STEAM-ELECTRIC PROGRAM (continued)

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| DATA(I,4) | Load factor, in percent x 10. | 29-33,<br>60-64 | F5.0 |
| DATA(I,8) | Annual hours of operation. | 34-38,<br>65-69 | F5.0 |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| | **Main Program** |
| ANN | Subroutine which calculates annual cost and emissions for scrubbed systems. |
| ASH | Plant's coal ash content, as a percent. In COMMON. |
| AVSIZE | Size of control system, for use in INV and ANN (qq.v.) |
| C1(I) | Array containing control costs for plant: C1(1) is investment cost, C1(2) is annual cost. |
| C2(I,IREG) | Array where costs C1 are accumulated by aggregate region IREG. |
| CEM | Subroutine which calculates 1967 and final emission from coal-burning where (1) is involved in a fuel switch, or (2) no changes are required. |
| CX | Variable which is used to check whether total fuel utilization is 99 percent or more. |
| DATA | Array which is used to store boiler input data. |
| DINV | Variable which transfers investment cost from INV to ANN. |
| E1 | Array which stores 1967 and final particulate emissions for the current plant. |
| E2 | Same as E1 for sulfur oxide emissions. |
| E3 | Accumulates E1 by aggregate region. |
| E4 | Accumulates E2 by aggregate region. |
| EFACT | Array containing premium costs of low-sulfur coal and oil. In COMMON. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| | Main Program |
| F | Array containing values used in calculating annual costs for scrubbing systems. |
| FSWC,FSWO | Subroutine which calculates annual costs of switching to low-sulfur fuels. |
| I | Dummy variable for indexing. |
| IAUX | Auxiliary code (not used in this program). |
| ICARD | Card type code (1 for plant I.D. card, 2 for boiler data card). |
| ICODE | Source identification code. |
| INPUT | Array which stores plant name and location. |
| INV | Subroutine which calculates investment cost of scrubbing systems. |
| IP | Line counter. |
| IREG | Aggregate region number (1 = metropolitan areas 1-40, 2 = metropolitan areas 41-298, 3 = outside metropolitan areas, 4 = unknown). |
| J | Dummy variable for indexing. |
| K | Dummy variable for indexing. |
| L | Dummy variable for indexing. |
| M | Dummy variable for indexing. |
| MBOIL | Temporary variable for determining number of boiler cards to be read in. |
| NBOIL | Number of boiler groups to be read in and costed (card type 2, 2 groups/card). |
| OEM | Subroutine similar to CEM, for oil burning. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| | Main Program |
| OUTFI | Subroutine for punching output data to be used subsequently in the system (currently a dummy). |
| RSAC1,RSAC2 | RSAC codes to be entered eventually in place of IREG. |
| S | Coal-equivalent fuel sulfur content. |
| SC | Temporary variable for coal sulfur content. |
| SCOAL | Coal sulfur content. In COMMON. |
| SO | Temporary storage for oil sulfur content. |
| SOIL | Oil sulfur content. In COMMON. |
| STACK | Arbitrarily calculated number of scrubbing systems. 1.0 unless AVSIZE > 1000 MW, when AVSIZE is successively halved and STACK doubled until AVSIZE $\leq$ 1000 MW. |
| | Subroutine CEM |
| ASH | Coal ash content. In COMMON. |
| CCOAL,COIL | Dummy variable in COMMON. |
| DATA | Array of boiler data. |
| E1,E2 | Arrays to accumulate particulate and sulfur oxide emissions. |
| M,NUM | Index of boiler data in DATA. |
| SCOAL,SOIL | Coal and oil sulfur contents. In COMMON. |
| TCOAL | Total coal used, 1967 (tons). |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| | Subroutine OEM |
| ASH | Coal ash content. In COMMON. |
| CCOAL,COIL | Dummy variable in COMMON. |
| DATA | Array of boiler data. |
| E1,E2 | Arrays to accumulate particulate and sulfur oxide emissions. |
| M,NUM | Index of boiler data in DATA. |
| SCOAL,SOIL | Coal and oil sulfur contents. In COMMON. |
| TOIL | Total oil used, 1967 (barrels). |
| | Subroutine FSWC |
| ASH | Coal ash content. IN COMMON. |
| CCOAL,COIL | Dummy variable in COMMON. |
| CI | Array for accumulating costs. |
| DATA | Array of boiler data. |
| M | Index of boiler data in array DATA. |
| NUM | Dummy variable for M. |
| PREMC,PREMO | Premium costs of low-sulfur coal and oil. In COMMON. |
| PROD | MWH of electricity production, 1967. |
| PRODC | KWH generated by coal, 1967. |
| SCOAL,SOIL | Percentage of coal and oil sulfur. In COMMON. |
| TCOAL | Total coal used, 1967 (tons). |
| | Subroutine FSWO |
| ASH | Coal ash content. In COMMON. |
| CCOAL,COIL | Dummy variable in COMMON. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| C1 | Array for accumulating costs. |
| DATA | Array of boiler data. |
| M | Index of boiler data in array DATA. |
| NUM | Dummy variable for M. |
| PROD | MWH of electricity produced, 1967. |
| PRODO | KWH of electricity generated by oil, 1967. |
| SCOAL,SOIL | Percentages of oil and coal sulfur. In COMMON. |
| TOIL | Total oil used, 1967 (barrels). |
| | Subroutine INV |
| CI | Array for accumulating costs. |
| S | Coal-equivalent fuel sulfur content. |
| SIZE | Size of control system, MW. |
| STACK | Number of control systems. |
| | Subroutine ANN |
| CAP | Number of hours operated, 1967. |
| CI | Array for accumulating costs. |
| DANN | Annualized cost after correction for load factor and coal/oil ratio. |
| DUM | Number of control systems required. |
| E1,E2 | Arrays for accumulating particulate and sulfur oxide emissions. |
| F | Array of cost factors for labor, water, etc. for scrubbing operations. |
| FACT | Boiler load factor. |
| S | Array of coal ash and coal and oil sulfur contents. In COMMON. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| SC,SO | Coal and oil fuel sulfur contents. |
| SIZE | Size of control system required; corrected to include only coal and oil fractions. |
| SS | Coal-equivalent sulfur content of all fuels. |
| TCOAL | Fraction of coal used; converted to total cost used (tons). |
| TOIL | Fraction of oil used; converted to total oil used (barrels). |
| X | Investment cost as calculated by Subroutine INV. |
| Y | Initial annual cost not corrected for load factor. |

## V. LISTING OF COMPUTER PROGRAM FOR STEAM-ELECTRIC

```
C   PROGRAM SELEC
C   THIS PROGRAM CALCULATES COSTS AND EMISSIONS FOR STEAM-ELECTRIC POWER
C   PLANTS.
C
C   DATA FOR EACH BOILER FOR EACH PLANT AVAILABLE, ALONG WITH FUEL USE
C   DATA AND FUEL ASH AND SULFUR CONTENT.
C
C   CONTROL PATTERNS AREO (1) ALL GAS-FIRED BOILERS ARE IGNORED;  (2)
C   COAL- OR OIL-FIRED BOILERS IN PLANTS LESS THAN 200 MW CAPACITY ARE
C   SWITCHED, WHERE NECESSARY, TO LOW-SULFUR FUELS; (3) PLANTS OF GREAT-
C   ER THAN 200 MW CAPACITY ARE CONTROLLED BY SWITCH TO LOW-SULFUR COAL
C   OR OIL, WHERE NECESSARY, IF THE LOAD FACTOR IS LESS THAN 1770; (4)
C   PLANTS OF GREATER THAN 200 MW CAPACITY AND 17( OR GREATER LOAD FAC-
C   TOR ARE CONTROLLED BY DOLOMITE-INJECTION/VENTURI SCRUBBERS, IF FUELS
C   ARE HIGH-SULFUR TYPE; (5) ALL BOILERS OF 90( OR GREATER GAS UTILI-
C   ZATION HAVE REMAINING FUELS SWITCHED TO LOW-SULFUR TYPE, IF NECES-
C   SARY.  OTHER ASSUMPTIONS PROGRAMMED INO (1) 86( OF PARTICULATES ARE
C   CONTROLLED IN 1967; (2) DOLOMITE-INJECTION PROCESS CONTROLS 99( OF
C   PARTICULATES AND 90( OF SULFUR OXIDES.
C
C   SCRUBBING SYSTEMS ARE ASSIGNED AS FOLLOWSO (1) ALL BOILERS OF LESS
C   THAN 25 MW CAPACITY ARE COMBINED INTO ONE SCRUBBING SYSTEM; (2) ALL
C   BOILERS WITH IDENTICAL DATA ARE COMBINED INTO ONE SCRUBBING SYSTEM;
C   (3) IF ANY RESULT OF (1) OR (2) RESULTS IN A CAPACITY GREATER THAN
C   1000 MW, THAT CAPACITY IS REPEATEDLY HALVED UNTIL THE RESULT IS LESS
C   THAN 1000 MW, AND THE RESULTING COSTS AND EMISSIONS ARE MULTIPLIED
C   BY THE APPROPRIATE POWER OF 2.
C
C   ALL PLANTS OF CAPACITY LESS THAN 25 MW ARE BYPASSED.
C
      DIMENSION  DATA(40,8),  EFACT(4), C1(2), E1(2), E2(2), C2(2,4),
     1 INPUT(12), E3(2,4), E4(2,4), F(6)
      COMMON ASH, SCOAL, SOIL, EFACT
C
C   ZERO DATA STORAGE
C
      DO 15 I=1,40
      DO 10 J=1,8
      DATA(I,J)=0.0
   10 CONTINUE
   15 CONTINUE
      DO 20 I=1,4
      EFACT(I)=0.
      DO 20 J=1,2
      C2(J,I)=0.
      E3(J,I)=0.
      E4(J,I)=0.
   20 CONTINUE
      KBOIL=0
      TOT=0.
      T=0.
      PRINT 5110
 5110 FORMAT(1H-,47X,27HSTEAM-ELECTRIC POWER PLANTS,/)
```

```
      PRINT 5111
 5111 FORMAT(1H ,80X,16HEMISSIONS (TONS),13X,11HFUEL SULFUR,/,52X,12HCOS
     1TS ($000)11X,12HPARTICULATES,7X,13HSULFUR OXIDES,3X,11HCONTENT (()
     2./,8X,5HPLANT,22X,8HLOCATION,6X,18HINVESTMENT  ANNUAL,7X,4H1967,5X
     3 5HFINAL,5X,4H1967,6X,5HFINAL,2X,10HCOAL   OIL,/)
      IP=4
C
C   READ DATA FOR CONTROL PARAMETERS.  EFACT CONTAINS (1) + (2)--DUMMY
C   VALUES; (3) + (4) PREMIUM COSTS PER TON OF COAL AND PER BARREL OF
C   OIL, DESULFURIZED, IN THOUSANDS OF DOLLARS.  F CONTAINS COSTS FOR
C   CALCULATING ANNUALIZED COSTSO (1) LIMESTONE COST, IN THOUSANDS OF
C   DOLLARS PER TON; (2) COST OF LABOR, IN DOLLARS PER MAN-HOUR; (3)
C   COST OF WATER, IN THOUSANDS OF DOLLARS PER MILLION GALLONS; (4) COST
C   OF ELECTRICITY, IN THOUSANDS OF DOLLARS PER MILLION KWH; (5) COST OF
C   TECHNICAL LABOR, IN THOUSANDS OF DOLLARS PER MAN-HOUR; AND (6) FRAC-
C   TION OF INVESTMENT DEPRECIATED ANNUALLY.
C
      READ 5000, EFACT, F
 5000 FORMAT(10F8.5)
   30 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      E2(1)=0.
      E2(2)=0.
C
C   READ DATA CARD TYPE 1.
C
      READ 5010, ICARD, IAUX, ICODE, IREG, NBOIL, DATA(1,3), ASH, SCOAL,
     1 SOIL, INPUT
 5010 FORMAT(I2,I1,I2,I4,I3,F7.0,F3.0,2F4.0,12A4)
      IF (ICARD-1) 1000,40,2000
   40 IF (IAUX-1) 2010,50,2010
   50 IF (ICODE-2) 2020,60,2020
C
C   READ DATA CARD(S) TYPE 2.
C
   60 MBOIL=NBOIL/2
      IF (MBOIL) 90,90,70
   70 DO 80 M=1,MBOIL
      K=M*2-1
      L=K+1
      READ 5015, ICARD, IAUX, ICODE, (DATA(I,1), DATA(I,2), (DATA(I,J),
     1 J=5,7), DATA(I,4), DATA(I,8),I=K,L)
 5015 FORMAT(I2,I1,I2,4X,F4.0,F6.0,3F3.0,2F5.0,2X,F4.0,F6.0,3F3.0,2F5.0)
   80 CONTINUE
   90 I=NBOIL-2*MBOIL
      IF (I) 110,110,100
  100 I=NBOIL
      READ 5015, ICARD, IAUX, ICODE,  DATA(I,1), DATA(I,2), (DATA(I,J),
     1 J=5,7), DATA(I,4), DATA(I,8)
  110 IF (ICARD-1) 1000,2000,120
  120 IF (IAUX-1) 2010,130,2010
  130 IF (ICODE-2) 2020,500,2020
C
C   DO PLANT CALCULATIONS.
C
  500 IF (DATA(1,3)-25 ) 595,530,520
  520 IF (DATA(1,3)-200.) 530,530,600
```

```
C
C     COSTS AND EMISSIONS FOR PLANTS LESS THAN 200 MW.
C
  530 DO 560 I=1,NBOIL
C
C     NO COSTS OR EMISSIONS IF THE BOILER IS 100( GAS.
C                                                                        D2  0710
      IF (DATA(I,7)-100.) 540,560,560
C                                                                        D2  0730
C     FUEL SWITCH FOR OTHER BOILERS.                                     D2  0740
C                                                                        D2  0750
  540 IF (SCOAL-1.) 550,550,545
  545 CALL FSWC (I,DATA,C1)
  550 CALL CEM(I,DATA,E1,E2)
      IF (SOIL-1.38) 556,556,555
  555 CALL FSWO(I,DATA,C1)
  556 CALL OEM(I,DATA,E1,E2)
  560 CONTINUE                                                           D2  0770
  570 PRINT 5020, INPUT, C1, E1, E2, SCOAL, SOIL                         D2  0780
 5020 FORMAT(1X,12A4,6F10.2,2F6.2)
      CALL OUTFI(RSAC1,RSAC2,IREG, 2,INPUT,C1,2,1,E1,2,E2)               D2  0801
C
C     CONVERT AGGREGATE REGION NUMBER FOR ACCUMULATED OUTPUT.
C
      DO 590 I=1,2                                                       D2  0862
      C2(I,IREG)=C2(I,IREG)+C1(I)                                        D2  0863
      E3(I,IREG)=E3(I,IREG)+E1(I)                                        D2  0864
      E4(I,IREG)=E4(I,IREG)+E2(I)                                        D2  0865
  590 CONTINUE
  595 CONTINUE
  580 IF (IP-56) 597,596,596
  596 PRINT 5110
      PRINT 5111
      IP=5
  597 IP=IP+1
      GO TO 30                                                           D2  0880
C                                                                        D2  0890
C     COSTS AND EMISSIONS FOR PLANTS GREATER THAN 200 MW.                D2  0900
C                                                                        D2  0910
  600 DO 640 I=1,NBOIL                                                   D2  0920
C
C     MAKE SURE THAT FUEL UTILIZATION FRACTIONS ADD UP TO AT LEAST .99.
C
      CX=0.
      DO 601 J=5,7
      CX=CX+DATA(I,J)
  601 CONTINUE
      IF (CX-99.) 640,605,605
  605 IF (DATA(I,7)-100.) 610,640,640                                    D2  0930
C                                                                        D2  0940
C     NO COSTS OR EMISSIONS FOR 100(-GAS BOILERS.  FUEL SWITCH FOR BOILERSD2  0950
C     WITH 90(-99( GAS, OR LOAD FACTOR OF 17( OR LESS.                   D2  0960
C                                                                        D2  0970
  610 IF (DATA(I,7)-90 ) 620,625,625                                     D2  0980
  620 IF (DATA(I,4)-169.) 625,625,640
  625 IF (SCOAL-1.) 635,635,630
  630 CALL FSWC(I,DATA,C1)
  635 CALL CEM(I,DATA,E1,E2)
      IF (SOIL-1.38) 637,637,636
  636 CALL FSWO(I,DATA,C1)
  637 CALL OEM(I,DATA,E1,E2)
  640 CONTINUE                                                          02  1020
      IF (DATA(1,4)-169.) 570,570,650
C                                                                       02  1110
C   CALCULATE SIZE OF CONTROL SYSTEM(S), COSTS, AND EMISSIONS.  INVEST-
C   MENT COST FOR THE PLANT IS ACCUMULATED IN C1(1), ANNUAL COST IN
C   C1(2), 1967 AND CONTROLLED EMISSIONS IN E1 FOR PARTICULATES AND E2
C   FOR SULFUR OXIDES.
C                                                                       02  1150
  650 DO 740 I=1,NBOIL
      IF (DATA(I,7)-90 ) 660,740,740
C
C   CALCULATE CONTROL SYSTEM SIZE.
C
  660 J=I
      IF (DATA(I,2)-25 ) 680,670,670
  670 K=J
      AVSIZE=DATA(K,1)*DATA(K,2)
      DATA(K,1)=1.0
      DATA(K,2)=AVSIZE
      GO TO 705
  680 K=NBOIL
      AVSIZE=0.0
      DO 700 L=J,K
      AVSIZE=AVSIZE+DATA(L,2)*DATA(L,1)
  700 CONTINUE
      DATA(K,2)=AVSIZE
      DATA(K,1)=1.0
      I=NBOIL
C
C   CALCULATE WEIGHTED AVERAGE FUEL SULFUR CONTENT ON A COAL-EQUIVALENT
C   BTU BASIS.
C
  705 SC=SCOAL
      SO=SOIL
      S=(SO*DATA(K,6)/1.38+SC*DATA(K,5))/100.
      STACK=1.0
  710 IF (AVSIZE-1000.) 730,730,720
  720 AVSIZE=AVSIZE/2.
      STACK=STACK*2.
      GO TO 710
  730 IF (S-1.0) 732,732,731
C
C   CALCULATE COSTS AND EMISSIONS
C
  731 CALL INV(STACK,AVSIZE,C1,S,DINV)
      CALL        ANN(STACK,AVSIZE,DINV,S,DATA(K,4),C1,E1,E2,DATA(K,5),
     1 DATA(K,6),DATA(K,8),SC,SO,F)
      I=K
      GO TO 740
C
C   CALCULATE EMISSIONS WHEN WEIGHTED AVERAGE FUEL IS LOW-SULFUR.
C
  732 CALL CEM(K,DATA,E1,E2)
      CALL OEM(K,DATA,E1,E2)
  740 CONTINUE
      GO TO 570
C
```

```
C   ERROR ROUTINES
C
 2000 PRINT 5035, INPUT
 5035 FORMAT(26H INVALID CARD TYPE CODE.  12A4)
      GO TO 30
 2010 PRINT 5040, INPUT
 5040 FORMAT(26H INVALID AUXILIARY CODE.  12A4)
      GO TO 30
 2020 PRINT 5045, INPUT
 5045 FORMAT(28H INVALID SOURCE TYPE CODE.  12A4)
      GO TO 30
C
C   END ROUTINE.  PRINT AGGREGATE REGION TOTALS AND STOP.
C
 1000 PRINT 5025, C2, E3, E4
 5025 FORMAT(1H-,52X,15HREGIONAL TOTALS,//,54X,12HCOSTS ($000),//,50X,
     1 21HINVESTMENT      ANNUAL,/,39X,10HREGION 1   ,2F11.0,/,39X,10HREGI
     2ON 2  ,2F11.0,/,39X,10HREGION 3  ,2F11.0,/,39X,10HREGION 4  ,2F11.
     30,//,36X,28HPARTICULATE EMISSIONS (TONS),//,56X,15H1967      FINAL
     4/39X,10HREGION 1  ,2F11.0,/,39X,10HREGION 2  ,2F11.0,/,39X,10HREGI
     5ON 3  ,2F11.0,/,39X,10HREGION 4  ,2F11.0,//,35X,29HSULFUR OXIDE EM
     6ISSIONS (TONS),//,56X,15H1967      FINAL,/,39X,10HREGION 1  ,2F11.
     70,/,39X,10HREGION 2  ,2F11.0,/,39X,10HREGION 3  ,2F11.0,/,39X,10HR
     8EGION 4  ,2F11.0)
      PRINT 5030
 5030 FORMAT(12H-GOOD FINISH)
      STOP
      END
      SUBROUTINE FSWC(NUM,DATA,C1)
C
C   THIS SUBROUTINE CALCULATES THE COSTS AND EMISSIONS (BEFORE AND AFTER
C   SWITCHING) FOR SWITCH FROM HIGH-SULFUR FUELS TO LOW SULFUR FUELS.
C
      DIMENSION DATA(40,8), C1(2)
      COMMON ASH, SCOAL, SOIL,       CCOAL, COIL, PREMC, PREMO
      M=NUM
C
C     CALCULATE MWH/YR GENERATED BY THE BOILER.
C
      PROD=DATA(M,2)*DATA(M,4)*DATA(M,8)*DATA(M,1)
C
C   CALCULATE KWH/YR GENERATED BY COAL, 1967.
C
      PRODC=PROD*DATA(M,5)/100.
C
C   CALCULATE TONS OF COAL USED/YEAR, AND COSTS OF SWITCH, 1967.
C
      IF (PRODC) 30,30,10
   10 TCOAL=PRODC*3.846E-4
   20 C1(2)=C1(2)+TCOAL*PREMC
   30 RETURN
      END
      SUBROUTINE FSWO(NUM,DATA,C1)
      DIMENSION DATA(40,8), C1(2)
      COMMON ASH, SCOAL, SOIL, CCOAL, COIL, PREMC, PREMO
      M=NUM
      PROD=DATA(M,2)*DATA(M,4)*DATA(M,8)*DATA(M,1)
C
C   CALCULATE BARRELS OF OIL USED, 1967, AND COSTS OF SWITCH.
```

```
C                                                                        D2  1990
      PRODO=PROD*DATA(M,6)/100.                                          D2  1860
   50 IF (PRODO) 100,100,60                                              D2  2000
   60 TOIL=PRODO*.0017                                                   D2  2010
   70 C1(2)=C1(2)+TOIL*PREMO                                             D2  2030
  100 RETURN
      END                                                                D2  2120
      SUBROUTINE INV(STACK,SIZE,C1,S,X)
C                                                                        D2  2310
C   THIS SUBROUTINE CALCULATES INVESTMENT COSTS FOR LIME SCRUBBING.
C                                                                        D2  2340
      DIMENSION C1(2)                                                    D2  2350
   10 X=((10816.35+943.19*S        )-(4.584*SIZE+.396*S        *SIZE))*  D2  2380
     1 SIZE                                                              D2  2390
      X=X/1000.*STACK
      C1(1)=C1(1)+X
      RETURN                                                             D2  2430
      END                                                                D2  2440
      SUBROUTINE ANN(DUM,SIZE,X,SS,FACT,C1,E1,E2,TCOAL,TOIL,CAP,SC,SO,F)
C                                                                        D2  2510
C   THIS SUBROUTINE CALCULATES ANNUAL COSTS FOR WET-LIME SCRUBBING FOR   D2  2520
C   STACKS IN TWO RANGESO 25-1000 MW AND  1000 MW.                       D2  2530
C                                                                        D2  2540
      DIMENSION C1(2),E1(2),E2(2),S(3), F(6)
      COMMON S
      SIZE=(SIZE*TCOAL+SIZE*TOIL*.95)/100.
C
C   CALCULATE COAL AND OIL USED.
C
      TOIL=TOIL*SIZE*CAP*FACT*1.7E-5
      TCOAL=TCOAL*SIZE*CAP*FACT*3.846E-5
C
C   CALCULATE BASIC ANNUALIZED COST.
C
      Y=(112.67*SS-8.33)*SIZE*F(1)+((.0234+.00995*SS)*SIZE+.7735*SS
     1 +7.38)*F(2)+.432*SS*SIZE*F(3)+(.06576-(.01134-.0024*SS)*SS)*SIZE
     2*F(4)+(.3871-.0001725*SIZE+.03535*SS-1.575E-5*SS*SIZE)*SIZE
     3 +(11.799-.00536*SIZE)*SIZE*F(5)+X*F(6)
      Y=Y*DUM
   30 IF (FACT-640.) 40,50,50
   40 IF (FACT-330.) 100,70,70
C                                                                        D2  2650
C   CORRECT FOR LOAD FACTOR GREATER THAN 64(
C                                                                        D2  2680
C   COAL                                                                 D2  2710
C                                                                        D2  2720
   50 DANN=(((910.-FACT)/10. *.00855*Y)+Y)*(TCOAL/(3000.*SIZE))          D2  2730
C
C   OIL
C
   60 DANN=DANN+(((910.-FACT)/10.*.00855*Y)+Y)*(TOIL/(12808.*SIZE))*.95
      GO TO 110
C
C   CORRECT FOR LOAD FACTOR BETWEEN 33( AND 64(.
C
   70 DANN= ((1.23+(640.-FACT)/10.*.0255)*Y)*(TCOAL/(3000.*SIZE))
   90 DANN=DANN+ ((1.2309+(640.-FACT)/10.*.0256)*Y)*(TOIL/(12808.*SIZE))
      GO TO 110
C
```

```
C     CORRECT FOR LOAD FACTOR LESS THAN 330.
C
  100 DANN=(2.0246*Y+(329.-FACT)/10.*.0967*Y)*(TCOAL/(3000.*SIZE))
      DANN=DANN+(2.0246*Y+(329.-FACT)/10.*.0967*Y)*(TOIL/(12808.*SIZE))
  110 SIZE=SIZE*DUM
      C1(2)=C1(2)+DANN
C
C     CALCULATE EMISSIONS.
C
      E1(1)=E1(1)+TCOAL*S(1)*1.1648E-3+TOIL*2.989E-5
      E1(2)=E1(2)+TCOAL*S(1)*8.32E-5+TOIL*2.135E-6
      E2(1)=E2(1)+TOIL*S(3)*5.30E-4+TCOAL*S(2)*1.90E-2
      E2(2)=E2(2)+TOIL*SO*5.30E-5+TCOAL*SC*1.90E-3
      RETURN
      END
      SUBROUTINE CEM(NUM,DATA,E1,E2)
C
C     THIS SUBROUTINE CALCULATES EMISSIONS FROM COAL BURNING WHEN SCRUB-
C     BING IS NOT APPLIED.
C
      DIMENSION DATA(40,8), E1(2), E2(2)
      COMMON ASH, SCOAL, SOIL, CCOAL, COIL
      M=NUM
      TCOAL=DATA(M,2)*DATA(M,4)*DATA(M,5)*DATA(M,8)*3.846E-6*DATA(M,1)
      IF (SCOAL-1.0) 30,30,20                                           02  1911
   20 E1(2)=E1(2)+TCOAL* ASH*1.1648E-3
      E2(2)=E2(2)+TCOAL*1.90E-2                                         02  1940
   30 E1(1)=E1(1)+TCOAL*ASH*1.1648E-3                                   02  1950
      E2(1)=E2(1)+TCOAL*SCOAL*1.90E-2                                   02  1960
      IF (SCOAL-1.0) 40,40,50                                           02  1961
   40 E1(2)=E1(2)+TCOAL*ASH*1.1648E-3                                   02  1962
      E2(2)=E2(2)+TCOAL*SCOAL*1.90E-2                                   02  1963
   50 RETURN
      END
      SUBROUTINE OEM(NUM,DATA,E1,E2)
C
C     THIS SUBROUTINE PARALLELS SUBROUTINE CEM FOR OIL BURNING.
C
      DIMENSION DATA(40,8), E1(2), E2(2)
      COMMON ASH, SCOAL, SOIL, CCOAL, COIL
      M=NUM
      TOIL=DATA(M,2)*DATA(M,4)*DATA(M,6)*DATA(M,8)*1.7E-5*DATA(M,1)
      IF (SOIL-1.38) 80,80,70                                           02  2020
   70 E2(2)=E2(2)+TOIL*7.314E-4
   80 E1(1)=E1(1)+TOIL*2.989E-5                                         02  2060
      E1(2)=E1(2)+TOIL*2.989E-5                                         02  2070
      E2(1)=E2(1)+TOIL*SOIL*5.30E-4                                     02  2080
      IF (SOIL-1.38) 90,90,100                                          02  2090
   90 E2(2)=E2(2)+TOIL*SOIL*5.30E-4                                     02  2100
  100 RETURN
      END
      SUBROUTINE OUTFI(A,D,C)
      RETURN
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

```
2 50    1.75  .00085   .0008  .00205     4.      .1      4.    .0075      .2
```

# APPENDIX C

## Computer Program for Asphalt Batching

# Appendix C

## Computer Program for Asphalt Batching

### I. INTRODUCTION

The asphalt batching industry contributes to air pollution by emitting particulates in the form of fine dust. The purpose of this computer program is to calculate the amount of these emissions and the costs of controlling them. The data for the asphalt batching industry are of such an uncertain quality that three types of data handling have been included in this program: (1) model plant technique, which uses a weighted average unit process size as plant capacity; (2) plant capacity technique, which uses total plant capacity and assumes one unit process per plant; and (3) detailed data method in which complete data are available for each unit process in the plant. The flow chart for the program logic is shown in Figure C-1.

Section II gives the major assumptions in the program. Section III explains the program logic; Section IV is a glossary of FORTRAN names; and Section V is a listing of the computer program.

### II. MAJOR ASSUMPTIONS

The assumptions upon which the calculations of cost and emissions are based are as follows:

a) Particulates are the only emission.

b) Costs can be calculated by table lookups with linear interpolation between points.

c) The bases for costs and emissions given to APCO for this report are: $5,940/ton/hour of capacity is the average investment cost; $4,450/ton/hour of capacity is the average annual cost; multicyclone collector for equipment of 90 tons/hr. or less; and 15-in. w.g. venturi for larger equipment.

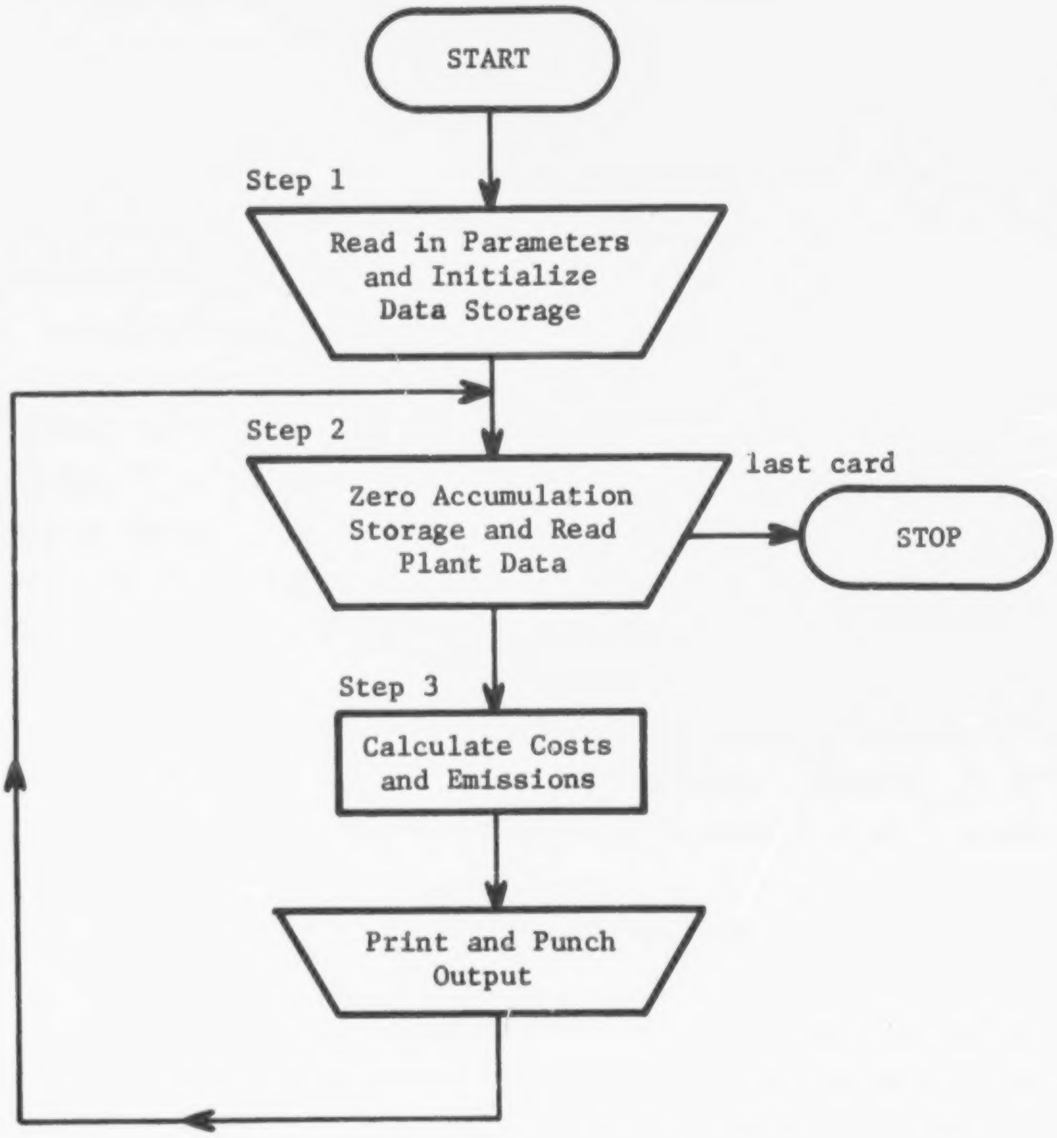

START
Step 1
Read in Parameters and Initialize Data Storage
Step 2
Zero Accumulation Storage and Read Plant Data
last card
STOP
Step 3
Calculate Costs and Emissions
Print and Punch Output

Fig. C-1. Flow Chart for Program BATCH.

## III. PROGRAM LOGIC

The steps in the program (see Figure C-1) are explained below.

Step 1.

Data storage is initialized and the emission factors and cost-capacity table are read in (see Table C-1 for details).

Step 2.

Vectors C1 and E1, which accumulate costs and emissions for each plant, are zeroed.

Plant data are read for one plant (see Table C-2 for details) using the standard input format.

Step 3.

Calculation procedures are provided for all three levels of data quality.

The model plant technique, where only plant location is known, is identified by IAUX = 2 in card 1. A pre-specified average capacity is used with average costs and emissions per unit capacity to produce the final plant costs and emissions.

The total capacity technique, where each plant's total capacity is known, is identified by IAUX = 1. In this case, the plant's total capacity rather than an average capacity is used similar to the model plant technique.

The detailed plant data technique (IAUX = 0) uses a table lookup routine with linear interpolation to determine costs and required control efficiencies for each unit process in the plant.

Step 4.

Costs and emissions are printed and, if desired, punched by Subroutine OUTFI. Control is then returned to Step 2 for reading data for the next plant. When all data have been read, the program stops.

## TABLE C-1. - PARAMETERS USED IN THE ASPHALT BATCHING PROGRAM

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| AVINV | Weighted average investment cost of control per ton per hour of capacity. | 1-8 | F8.4 |
| AVANN | Weighted average annualized cost of control per ton per hour of capacity. | 9-16 | F8.4 |
| AVCAP | Average capacity for use with plants of unknown capacity ("model plant" capacity). | 17-24 | F8.4 |
| | Cards 2-4 | | |
| TABLE(3,10) | This table gives the capacity and corresponding investment cost and annualized cost for up to ten entries. Card 2 contains the ten capacities, Card 3 the ten investment costs, and Card 4 the annualized costs. | 1-80 | 10F8.4 |
| | Cards 5-6 | | |
| RPCT(2,10) | This table gives the capacities and the corresponding required percentages of control of particulates according to the applicable standard. | 1-80 | 10F8.4 |

## TABLE C-2. - INPUT DATA DESCRIPTION

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| | Blank. | 1 | 1X |
| ICODE | Card identification. | 2 | I1 |
| IAUX | Plant data type (0 for detailed data, 1 for total capacity only, 2 for plant location only). | 3 | I1 |
| SCODE | Source type code (13). | 4-5 | F2.0 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| NPROC | Number of unit process within the plant (IAUX=0 only). | 11-12 | I2 |
| TOTCAP | Total plant capacity. | 13-22 | F10.0 |
| | Blank. | 23-30 | 8X |
| INPUT(12) | Plant name and location. | 31-78 | 12A4 |
| | Card 2 | | |
| | Same as Card 1. | 1-10 | 1X,I1,<br>I1,F2.0,<br>A4,A1 |
| | Blank. | 11-12,<br>31-33,<br>51-53 | 2X |
| IUNIT(10) | Number of units of process size. | 13-15,<br>33-35,<br>53-55 | I3 |
| CEFF(10) | Emission control level for the unit process (1967). | 16-17,<br>36-37,<br>56-57 | F2.0 |
| CAP(10) | Process capacity. | 18-25,<br>38-45,<br>58-65 | F8.0 |
| | Blank. | 26-30,<br>46-50,<br>66-70 | 5X |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Names | Definition |
|---|---|
| ANN | Temporary storage for unit process annual cost. |
| AVANN | Weighted average annualized cost per unit of capacity. |
| AVCAP | Average capacity for "model plant." |
| AVINV | Weighted average investment cost per unit of capacity. |
| C1(2) | Accumulation of (1) investment and (2) annual costs for plant totals. |
| CAP(10) | Input storage for individual unit process capacity. |
| CEFF(10) | Input storage for individual unit process emission control level (1967). |
| DINV | Temporary storage for unit process investment cost. |
| E1(2) | Accumulation of (1) 1967 and (2) fully-controlled emissions for plant totals. |
| I | Indexing parameter. |
| IAUX | Plant data type code. 0 for detailed data, 1 for total capacity data only, 2 for plant location data only. |
| ICODE | Card type code. |
| INPUT(12) | Input storage for plant name and location. |
| IUNIT(10) | Input storage for individual unit process number. |
| J | Indexing parameter. |

IV. Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| NPROC | Number of unit process descriptions appearing on cards type 2. |
| PCT(10) | Required control efficiency for an individual unit process as determined by table lookup and interpolation in RPCT (q.v.). |
| RPCT(2,10) | Table containing ten unit process sizes and corresponding control efficiencies based on the applicable standard. |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |
| SCODE | Source type code. |
| TABLE(3,10) | Table of process size and associated unit process investment and annual costs (10 entries). |

## V. LIST OF COMPUTER PROGRAM FOR ASPHALT BATCHING

```
C     PROGRAM ASPHALT
C     THIS PROGRAM CALCULATES CONTROL COSTS FOR THE ASPHALT BATCHING
C     INDUSTRY.
C
C     CARD TYPE 5 INDICATES TOTAL REQUIRED CAPACITY FOR AQCR (ANNUAL).
C     ANNUAL HOURS PER YEAR OF OPERATION CONTAINED BY AQCR IN ARRAY HR.
C     ACFM CALCULATED ASSUMING 150 ACFM/TON/HR.
C     90 TON/HR OR LESS USES MULTI-CYCLONE.  REST USE 15-IN. W.G. VENTURI.
C
      DIMENSION CEFF(10)
      DIMENSION     INPUT(12), IUNIT(10), CAP(10), PCT(10), RPCT(2,10)
C
C     INITIALIZE
C
      DO 10 I=1,12
      INPUT(I)=0
   10 CONTINUE
      AVINV=5.94
      AVANN=4.45
C
C     BEGIN INPUT WITH CARD TYPE 1.
C
   20 READ 5005, ICODE, IUX, SCODE, RSAC1, RSAC2, TOTCAP, NPROC, INPUT
 5005 FORMAT(1X,I1  ,I1  ,F2.0,A4,A1,F10.0,I2,12A4)
      C1=0.
      C2=0.
      E1=0.
      E2=0.
      IF (ICODE-1 ) 2000,30,1000
   30 IF (SCODE-13.) 1010,40,1010
   40 IF (IUX-1 ) 600,500,50
   50 READ 5010, ICODE,IUX,SCODE, (IUNIT(I),CEFF(I),CAP(I),I=1,NPROC)
 5010 FORMAT(1X,I1  ,I1  ,F2.0,7X,I3,F2.0,F8.0,7X,I3,F2.0,F8.0,7X,I3,
     1 F2.0,F8.0,/,(12X,I3,F2.0,F8.0,7X,I3,F2.0,F8.0,7X,I3,F2.0,F8.0/))
      IF (ICODE-2 ) 1030,60,1030
   60 IF (SCODE-13.) 1010,90,1010
C
C     LOOK UP PERCENTAGE CONTROL REQUIRED.
C
      DO 120 I=1,NPROC
      DO 120 J=1,10
      IF (CAP(I)-RPCT(1,J)) 110,110,120
  110 PCT(J)=RPCT(2,J)
  120 CONTINUE
C
C     CALCULATE INCREMENTAL CONTROL COSTS
C
      DO 160 I=1,NPROC
      IF(CAP(I)-13500.) 130,130,140
  130 CALL CYCLON(CAP(I),PCT(I),DINV,ANN)
      GO TO 150
  140 CALL VENTUR(CAP(I),PCT(I),15,DINV,ANN)
  150 C1=C1+DINV*FLOAT(IUNIT(I))
```

```
      C2=C2+ANN *FLOAT(IUNIT(I))
      E1=CAP(I)/150.*5 *2400.*FLOAT(IUNIT(I))                           13  0650
      E2=E1*(1.-PCT(I))                                                 13  0660
  160 CONTINUE                                                          13  0710
      PRINT 5016, INPUT, C1, C2, E1, E2
 5016 FORMAT(1X,12A4,4F12.3)
      GO TO 20                                                          13  0715
C                                                                       13  0720
C   AVERAGED COSTS FOR UNKNOWN UNIT PROCESS SIZE (SAME AS 1970 305(A)). 13  0730
C                                                                       13  0740
  500 C1=AVINV*TOTCAP
      C2=AVANN*TOTCAP                                                   13  0770
      E1=6.*TOTCAP
      E2=E1*.07                                                         13  0830
      PRINT 5016, INPUT, C1, C2, E1, E2
      GO TO 20                                                          13  0880
C
C   PLANT LOCATION ONLY.  MODEL PLANT TECHNIQUE (ONE PROCESS STREAM).
C
  600 C1(1)=C1(1)+14.231
      C1(2)=C1(2)+9.938
      E1(1)=E1(1)+325.
      E1(2)=E1(2)+26.
      PRINT 5555, INPUT, RSAC1, RSAC2, C1, E1
 5555 FORMAT(1X,12A4,2X,A4,A1,4F15.2)
      GO TO 20
C                                                                       13  0890
C   ERROR ROUTINES                                                      13  0900
C                                                                       13  0910
 1000 PRINT 5020, CCODE                                                 13  0920
 5020 FORMAT(19H INVALID CARD CODE,,F4.2,34H 1 EXPECTED.  SKIP TO NEXT 113  0930
     1 CARD.)                                                           13  0940
      GO TO 20                                                          13  0941
 1010 PRINT 5025, SCODE                                                 13  0950
 5025 FORMAT(21H INVALID SOURCE CODE ,F4.2,22H. SKIP TO NEXT 1 CARD.)   13  0960
      GO TO 20                                                          13  0970
 1030 PRINT 5035, CCODE                                                 13  1020
 5035 FORMAT(19H INVALID CARD CODE ,F3.0,23H.  SKIP TO NEXT 1 CARD.)    13  1030
      GO TO 20                                                          13  1050
C                                                                       13  1060
C   OUTPUT ROUTINE.  EACH CARD READ IN IS PRINTED OUT, AND CUMULATIVE   13  1070
C   TOTALS ARE PRINTED TO SHOW INTERMEDIATE RESULTS                     13  1080
C                                                                       13  1090
 2000 PRINT 5040                                                        13  1100
 5040 FORMAT(12H1GOOD FINISH)                                           13  1110
      STOP                                                              13  1120
      END                                                               13  1130
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

# APPENDIX D

## Computer Program for Brick and Tile

# Appendix D

## Computer Program for Brick and Tile

## I. INTRODUCTION

The only data currently available on the brick and tile industry are plant name and location. In computing cost and emissions, three methods of computations are designed within the program to allow for additional data as it becomes available. These methods are: (1) model plant technique, where each plant is assumed to have the same capacity (a weighted average); (2) total capacity technique, where each plant's capacity is known; (3) detailed data technique, where information is available for each process stream within a plant.

Figure D-1 is the flow chart for the brick and tile computer program.

The remainder of this appendix is organized as follows: Section II lists the specific assumptions on which the program is based; Section III describes in detail the program operations; Section IV is a glossary of FORTRAN names used; and Section V is a complete program listing, including parameters used for this report.

## II. ASSUMPTIONS

The assumptions made with regard to calculating control costs and emissions are:

a) Particulate emissions are reduced by 85 percent;
b) Ten percent of the emissions are particulate fluoride;
c) Gaseous fluoride emissions are reduced by 95 percent;
d) Model plant size is 172 tons/day.

Control costs and emissions computed in this program for the brick and tile industry are based on the above assumptions plus:

a) Uncontrolled emissions for the model plant are 3.2 tons/year fluoride particulates and 27.5 tons/year gaseous fluorides.

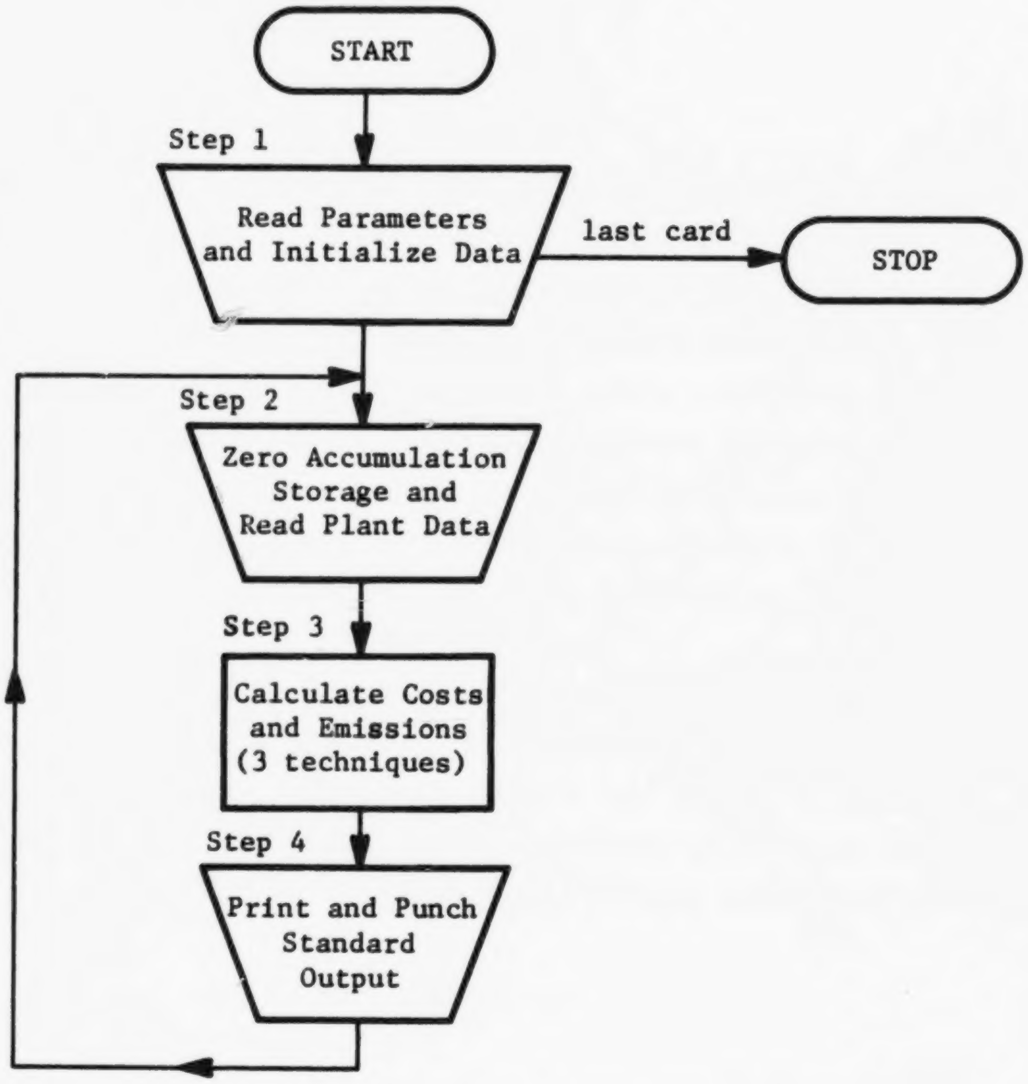

START
Step 1
Read Parameters and Initialize Data
last card
STOP
Step 2
Zero Accumulation Storage and Read Plant Data
Step 3
Calculate Costs and Emissions (3 techniques)
Step 4
Print and Punch Standard Output

Fig. D-1. - Flow Chart for the Brick and Tile Computer Program.

(b) Currently, brick and tile plants have no control installed.

(c) Costs for a cyclonic wet scrubber (Section V and Table D-1).

## III. PROGRAM OPERATIONS

Step numbers refer to the flow chart in Figure D-1.

### Step 1.

The arrays are initialized and the parameters, Table D-1, are read in.

### Step 2.

Data are read for each plant using the standard input procedure and format (see Table D-2 for details). The program is written to handle all possible types of plant data--model plant, total capacity only, or detailed data--as specified by the value of IAUX on card type 1. Cost and emissions accumulation variables are set to zero.

### Step 3.

Costs and emissions for the plant are calculated. If detailed plant data are supplied, investment and annual costs and 1967 and final emissions are calculated. A table lookup is used for costs; the table is to be supplied as part of the parameters in the input data. If a unit process size exceeds the table's maximum, the value is successively halved until it falls within the table and the resulting costs are multiplied by the appropriate power of two. Emissions are calculated from appropriate factors.

When plant data are encountered for which only its total capacity is known, costs and emissions are calculated using an average cost per ton and ton of emissions per ton.

When a "location only" plant data set are encountered, a total capacity of 162 tons/day is assigned and a "total capacity" calculation is performed.

### Step 4.

Standard output data are printed and punched using subroutine OUTFI if desired. Control is returned to Step 2 for further data and program terminates.

TABLE D-1. - LIST OF PARAMETERS FOR THE BRICK AND TILE PROGRAM

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| SIZE(10) | The column of capacity of unit processes used in table look-up procedure to determine costs. | 1-80 | 10F8.0 |
| | Card 2 | | |
| COST1(10) | Each entry is the investment cost of equipment to control a unit process of capacity in the corresponding element of SIZE. | 1-80 | 10F8.0 |
| | Card 3 | | |
| COST2(10) | Annualized cost similar to COST1 | 1-80 | 10F8.0 |
| | Card 4 | | |
| EM(2) | Uncontrolled emission factors in appropriate units. EM(1) is for all particulates (of which 10 percent are assumed to be fluorides) and EM(2) is for gaseous fluorides. | 1-16 | 2F8.0 |

TABLE D-2. - INPUT DATA DESCRIPTION FOR THE BRICK AND TILE PROGRAM

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| ICODE | Card identification | 1-2 | I2 |
| IAUX | Input type code (0 for detailed plant data, 1 for plant location data only, 2 for total capacity data). | 3 | I1 |
| SCODE | Source industry code (25 for Brick and Tile). | 4-5 | I2 |
| RSAC1 | Standard RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| NPROC | Number of unit processes to be found on card(s) 2 (used only when IAUX=0). | 11-12 | I2 |
| TOTCAP | Total plant capacity | 13-22 | F10.0 |
| | Blank. | 23-30 | 8X |
| INPUT(12) | Plant name and address | 31-78 | 12A4 |
| | Card 2 | | |
| | Blank. | 1-10 | 10X |
| IUNIT(10) | Type of unit process | 11-12,<br>31-32,<br>51-52 | I2 |
| NUM(10) | Number of each unit process at plant with identical data. | 13-15,<br>33-35,<br>53-55 | F3.0 |
| EFF(10) | Controlled efficiency of unit process (1967). | 16-17,<br>36-37,<br>56-57 | F2.0 |
| D(10) | Capacity of each unit within the group. | 18-25,<br>38-45,<br>58-65 | F8.0 |
| | Blank. | 26-30,<br>46-50,<br>66-70 | 5X |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| C1(2) | Vector to accumulate (1) investment and (2) annual control costs for the plant. |
| COST1(10) | Vector of investment costs associated with SIZE.* |
| COST2(10) | Vector of annual costs associated with SIZE.* |
| D(10) | Storage for individual unit process capacity. |
| E1(2) | Vector to accumulate (1) 1967, and (2) controlled, nonfluoride particulate emissions. |
| E2(2) | Vector like E1(2) for all fluoride emissions. |
| EFF(10) | Storage for individual unit process with 1967 control efficiency. |
| EM(2) | Emission factors for (1) all particulates and (2) gaseous fluorides. |
| F | Fraction for table lookup interpolation. |
| FACT | Accumulates power of 2 to compensate for halving of capacity during table lookup. |
| I | Indexing variable. |
| IAUX | Plant data type identification. |
| ICODE | Card type code. |
| INPUT(12) | Storage for name and address of plant. |
| IUNIT(10) | Storage for unit process type. |
| J | Indexing variable. |
| K | Indexing variable. |

---

* SIZE, COST1, and COST2 make up a 3-column, 10-entry table.

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| L | Indexing variable. |
| MPROC | Used to aid in input routine. |
| NPROC | Number of unit process data found on card type 2. |
| NUM(10) | Number of pieces of equipment with identical data in unit process. |
| SCODE | Source code. |
| SIZE(10) | Vector of capacities associated with COST1 and COST2.* |

---

* SIZE, COST1, and COST2 make up a 3-column, 10-entry table.

## V. LIST OF THE COMPUTER PROGRAM FOR BRICK AND TILE

```
C    PROGRAM BRKTIL
C    THIS PROGRAM CALCULATES CONTROL COSTS AND EMISSIONS FOR THE BRICK
C    AND TILE INDUSTRY.
C
C    STANDARD INPUT ROUTINE IS USED.  IAUX=1 SPECIFIES MODEL PLANT CAL-
C    CULATION, IAUX=2 SPECIFIES "TOTAL CAPACITY" CALCULATION, AND IAUX=0
C    SPECIFIES DETAILED DATA CALCULATION.
C
C    MODEL PLANT CALCULATION BASED ON 162 TONS/DAY OUTPUT.
C
C    COSTS AND EMISSIONS BASED ON CONTROL OF PARTICULATES TO 85( LEVEL,
C    95( CONTROL OF GASEOUS FLOURIDES, USE OF CYCLONIC WET SCRUBBERS,
C    AND ZERO INITIAL CONTROL.  TABLE LOOK-UP IS USED TO CALCULATE COSTS,
C    WITH LINEAR INTERPOLATION.  EMISSION PARAMETERS MUST BE SCALED TO
C    TONS/YEAR PER TON/DAY CAPACITY WITH ALLOWANCE FOR PRODUCTION LEVEL.
       DIMENSION SIZE(10), COST1(10), COST2(10), EM(2), IUNIT(10), D(10),
      1 EFF(10), NUM(10), C1(2), E1(2), E2(2), INPUT(12)
       INTEGER SCODE
       REAL NUM
C
C    INITIALIZE
C
       DO 10 I=1,10
       SIZE(I)=0.0
       COST1(I)=0.0
       COST2(I)=0.0
       EM(I)=0.0
       IUNIT(I)=0
       D(I)=0.0
       EFF(I)=0.0
       NUM(I)=0.0
    10 CONTINUE
C
C    READ PARAMETERS.
C
       READ 5000, SIZE, COST1, COST2, EM
  5000 FORMAT(10F8.0)
C
C    ZERO PLANT ACCUMULATION VECTORS.
C
    20 C1(1)=0.0
       C1(2)=0.0
       E1(1)=0.0
       E1(2)=0.0
       E2(1)=0.0
       E2(2)=0.0
C
C    READ PLANT DATA.
C
       READ 5005, ICODE, IAUX, SCODE, RSAC1, RSAC2, NPROC, TOTCAP, INPUT
  5005 FORMAT(I2,I1,I2,A4,A1,I2,F10.0,8X,12A4)
       IF (ICODE-1) 2000,30,1000
    30 IF (SCODE-25) 1010,40,1010
```

```
   40 IF (IAUX-1) 50,300,200
C
C    READ CARD TYPE 2.
C
   50 MPROC=NPROC/3
      IF (MPROC) 80,80,60
   60 DO 70 I=1,MPROC
      K=(I-1)*3+1
      L=K+2
      READ 5010, (IUNIT(J),NUM(J),EFF(J),D(J),J=K,L)
   70 CONTINUE
   80 MPROC=MPROC*3+1
      IF (NPROC-MPROC) 100,90,90
   90 READ 5010, (IUNIT(J),NUM(J),EFF(J),J=MPROC,NPROC)
 5010 FORMAT(10X,3(I2,F2.0,F3.0,F8.0,5X))
C
C    INITIALIZE FOR MULTIPLE-PROCESS PLANT
C
  100 MPROC=0
  110 MPROC=MPROC+1
      TOTCAP=D(MPROC)
      FACT=NUM(MPROC)
      CEFF=EFF(NPROC)
      GO TO 210
C
C    INITIALIZE FOR TOTAL CAPACITY OR MODEL PLANT CALCULATION.
C
  200 NPROC=0
      CEFF=0.0
      FACT=1.0
C
C    STANDARD CALCULATION ROUTINE
C
  210 DO 230 I=2,10
      IF (SIZE(I)-TOTCAP) 230,220,240
      F=(SIZE(I)-TOTCAP)/(SIZE(I)-SIZE(I-1))
      GO TO 250
  230 CONTINUE
      FACT=FACT*2.0
      TOTCAP=TOTCAP/2.0
      GO TO 210
  240 F=0.0
  250 C1(1)=C1(1)+(COST1(I)-(COST1(I)-COST1(I-1))*F)*FACT
      C1(2)=C1(2)+(COST2(I)-(COST2(I)-COST2(I-1))*F)*FACT
      E1(1)=E1(1)+TOTCAP*(1.-CEFF/100.)*EM(1)
      E1(2)=E1(2)+TOTCAP*EM(1)*.15
      E2(1)=E2(1)+TOTCAP*(EM(2)+EM(1)*.1)
      E2(2)=E2(2)+TOTCAP*(EM(2)*.05+EM(1)*.015)
      IF (NPROC) 270,270,260
  260 IF (NPROC-MPROC) 270,270,110
  270 PRINT 5015, RSAC1,RSAC2,INPUT,C1,E1,E2
 5015 FORMAT(1X,14A4,6F10.2)
      CALL OUTFI(RSAC1,RSAC2,AQCR,25,INPUT,C1,2,1,E1,5,E2)
      GO TO 20
C
C    INITIALIZE FOR MODEL PLANT CALCULATIONS.
C
      GO TO 200
  300 TOTCAP=162.
```

```
C
C    ERROR ROUTINES
C
 1000 PRINT 5020, ICODE, RSAC1, RSAC2
 5020 FORMAT(19H INVALID CARD CODE ,I2,15H FOUND IN CARD ,A4,A1)
      GO TO 20
 1010 PRINT 5025, SCODE, RSAC1, RSAC2
 5025 FORMAT(21H INVALID SOURCE CODE ,I3,15H FOUND IN CARD ,A4,A1)
      GO TO 20
C
C    END ROUTINE
C
 2000 PRINT 5030
 5030 FORMAT(12H1GOOD FINISH)
      STOP
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

# APPENDIX E

## Computer Program for Coal Cleaning

# Appendix E

## Computer Program for Coal Cleaning

## I. INTRODUCTION

The coal cleaning industry is limited to the actual washing or cleaning operations and the subsequent drying if required; and not to the related operation such as coal crushing, screening, or sizing. The coal is cleaned with air or water. Flash and fluidized-bed thermal driers are used for coal cleaned by wet methods and pneumatic cleaners are used for air drying. The major air pollution problem in the coal cleaning industry is the emission of particulates in the form of dust.

The purpose of this report is to describe a computer program designed to compute the emissions and associated costs for controlling the emissions inherent to the coal cleaning industry. The data base for the computation consist of plant name, location, and annual cleaned coal capacity. Ideal data would have given the types of processes; and the capacities, gas flow, and control efficiency of each process type. Due to the absence of ideal data, a model plant configuration was computed based on annual capacity. A general flow diagram of the computer logic is shown in Figure E-1.

Section II lists the major assumptions in the computer program. Section III explains the program logic and gives tables of input data with formats to enable one to use the program. Section IV is a Glossary of FORTRAN names and Section V is a listing of the computer program and control data.

## II. ASSUMPTIONS

The major assumptions made in regard to the calculations of emissions and costs for the computer program are as follows:

a) The annual hours of operation are 3750.

b) The amount of coal cleaned by pneumatic cleaners is 7.1 percent.

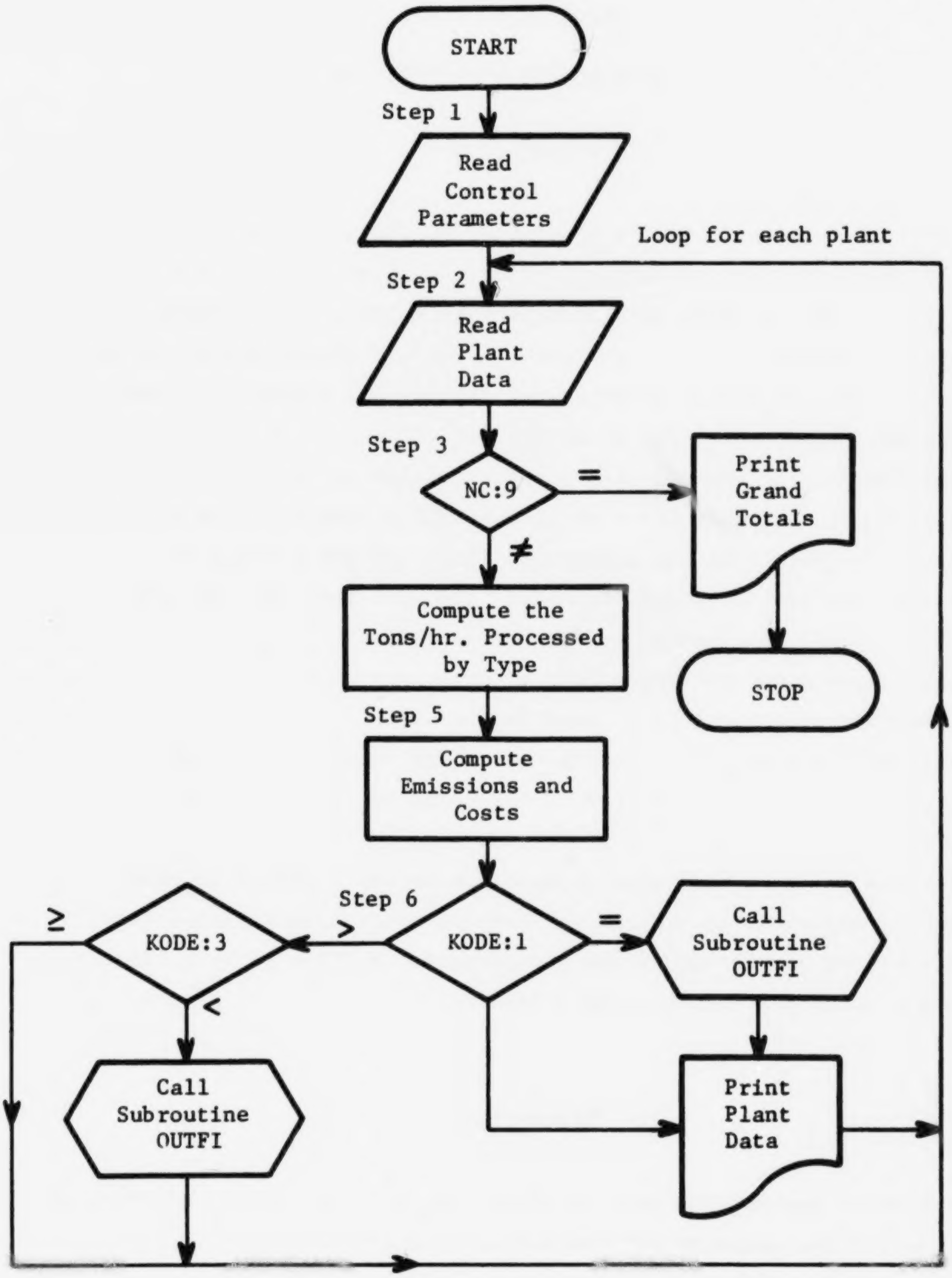

START
Step 1
Read Control Parameters
Loop for each plant
Step 2
Read Plant Data
Step 3
NC:9
=
Print Grand Totals
STOP
≠
Compute the Tons/hr. Processed by Type
Step 5
Compute Emissions and Costs
Step 6
KODE:1
=
Call Subroutine OUTFI
Print Plant Data
>
KODE:3
≥
<
Call Subroutine OUTFI

Fig. E-1. Flow Chart of Program COAL.

c) The amount of coal wet washed and thermally dried is 20.7 percent with 43.5 percent of that amount by fluidized-bed drier and 56.5 percent by flash drier.

d) The amount of coal wet washed and not thermally dried is 72.2 percent.

e) The control device for the fluidized-bed drier is a 16" w.g. venturi scrubber.

f) The control device for both the flash drier and the pneumatic cleaner use a 5" w.g. venturi scrubber.

## III. PROGRAM LOGIC

The object of this program is to compute the emissions of particulates, EM1(I), with I equal to 1 for uncontrolled emissions and 2 for controlled emissions. The investment and annualized operating costs are COST(1) and COST(2), respectively.

Step 1.

The first step in the program is to read in certain parameters as shown in Table E-1. When and if detailed plant data become available, the data in cards 2 thru 6 can be removed and read into the program on a plant by plant basis.

Step 2.

This is the beginning of a loop which reads in individual plant data consisting of one card per plant as shown in Table E-2.

Step 3.

Immediately after reading in the plant data, the value for NC is checked for a "9," in which case the grand totals are printed out and the program is terminated.

Step 4.

The total hourly rate capacity, HRC, is computed in order to determine the amount of coal processed by each of the three process types as follows:

a) Wet washed (20.7% of total) and flash dried (56.5%).

PROC(1) = 0.565HRC x 0.207

## TABLE E-1. - CONTROL PARAMETERS FOR PROGRAM COAL

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Code to denote when to bypass Subroutine OUTFI and/or when to print plant data. | 1-5 | I5 |
| | Card 2 | | |
| SIZE(I), I=1,3 | Model plant size for process type I. | 1-30 | 3F10.3 |
| | Card 3 | | |
| GVOL(I), I=1,3 | Gas flow (acfm/ton/hr.) for model plant of process type I. | 1-30 | 3F10.3 |
| | Card 4 | | |
| CEF1(I), I=1,3 | The 1967 control efficiency for process type I. | 1-30 | 3F10.3 |
| | Card 5 | | |
| CEF2(I), I=1,3 | The required control efficiency for process type I. | 1-30 | 3F10.3 |
| | Card 6 | | |
| CFAC(I), I=1,3 | Capital cost factor ($1000/ton/hr.) for process type I. | 1-30 | 3F10.3 |
| | Card 7 | | |
| AFAC(I), I=1,3 | Annual cost factor ($1000/ton/hr.) for process type I. | 1-30 | 3F10.3 |

TABLE E-2. - PLANT DATA FOR PROGRAM COAL

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| NC | Number of card. | 1-2 | I2 |
| | Blank | 3-5 | 3X |
| RSAC | National location code. | 6-9 | A4 |
| TOTCAP | Annual cleaned coal capacity (1000 tons). | 10-21 | F12.1 |
| | Blank | 22-30 | 9X |
| INP(I), I=1,12 | Name and location of plant. | 31-78 | 12A4 |

b) Wet washed (20.7% of total) and fluidized-bed dried (43.5%).

$$\text{PROC(2)} = 0.435 \times \text{HRC} \times 0.207$$

c) Pneumatically cleaned (7.1% of total).

$$\text{PROC(3)} = .071 \times \text{HRC}$$

This accounts for all but 72.2 percent of the total amount of coal which is wet washed and not thermally dried; therefore, not contributing to the air pollution.

Step 5.

Subroutine COSTEQ is called in order to return the cost of equipment, EQCOST(I), in thousands of dollars as a function of inlet gas volume, GVPPT(I), for each process type. The gas volume (1000 acfm) is computed as follows:

$$\text{GVPPT(I)} = \frac{\text{GVOL(I)} \times \text{CAP(I)}}{1000} \quad ,$$

where GVOL(I) is the gas flow (acfm/ton per hour) for each process type I, and CAP(I) is the size of the process type. The total investment cost for each process type I is then computed as:

$$\text{COST(I)} = 2.5\ \text{EQCOST(I)} + \text{SAVE(I)} \times \text{CFAC(I)},$$

where SAVE(I) is the amount of coal processed by a model plant size process. CFAC(I) is the capital cost factor ($1000/ton/hour) for the I-th process.

The annual direct operating costs, AOCOST(I), for venturi scrubbers is a function of inlet gas volume, GVPPT(I), (1000 acfm) and is computed by using analytical functions to represent the appropriate curve. The total annual costs for each process type is then computed as:

$$\text{COSTYR(I)} = 0.2\ \text{EQCOST(I)} + \text{SAVE(I)} \times \text{AFAC(I)},$$

where AFAC(I) is the I-th annual cost factor ($1000/ton/hour), and SAVE(I) is the same as explained above.

The total investment and annual costs are then computed as follows:

$$\text{COST(1)} = \sum_{I=1}^{I=3} \text{COSTI(I)}, \text{ and}$$

$$\text{COST(2)} = \sum_{I=1}^{I=3} \text{COSTYR(I)}.$$

The uncontrolled particulate emissions (tons) for each process is computed as:

$$EMU(I) = \frac{EMF(I) \times PROC(I) \times 3750}{2000.0}$$

where EMF(I) is the uncontrolled emissions (lbs/ton of coal feed) for the I-th process.

The 1967 emissions with and without added controls are then computed as:

$$EM1(1) = \sum_{I=1}^{I=3} EMU(I)\ [1.0 - CEF1(I)]\ ,\ \text{and}$$

$$EM1(2) = \sum_{I=1}^{I=3} EMU(I)\ [1.0 - CEF2(I)]$$

where CEF1(I) and CEF2(I) are the 1967 efficiency level (percent) and the required efficiency level (percent), respectively.

The costs and emissions are both summed in order to output a grand total after the last plant is processed.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

## GLOSSARY OF FORTRAN NAMES (Continued)

| FORTRAN Name | Definition |
|---|---|
| ICODE | Dummy variable for calling Subroutine OUTFI. |
| INP(12) | Name and address of plant. |
| ITEMP | Temporary storage location of number of processes of type I having a model plant type capacity (SIZE(I)). |
| JNE | Emission number arbitrarily assigned each pollutant and used to call Subroutine OUTFI. |
| NC | Card number. |
| NE | Total number of pollutants from source. |
| NS | Source number arbitrarily assigned to each source. |
| NUMB(4) | Total number required for each piece of control equipment type I. |
| PROC(3) | Coal cleaned (tons/hour) by the I-th process. |
| RSAC | National location code. |
| SAVE(3) | Multiples of model plant size processes I. |
| SIZE(3) | Model plant size for the I-th process. |
| SUM(4) | Sum of emissions and costs for all plants. |
| TEMP | Real value for ITEMP. |
| TOTCAP | Annual cleaned coal capacity, thousands of tons per year. |

## V. LISTING FOR COMPUTER PROGRAM COAL

```
C           PROGRAM COAL
C            THIS PROGRAM COMPUTES EMISSIONS AND COSTS FOR CONTROLLING
C          EMISSIONS IN THE COAL CLEANING INDUSTRY.
C
      INTEGER RSAC
      REAL NUMB
      DIMENSION GVPPT(4),EQUIP(4),EQCOST(4),NUMB(4),ADCOST(4),
     2SIZE(4),CFAC(3),AFAC(3),SAVE(3),COSTI(3),COSTYR(3),CEF1(3),CEF2(3)
      DIMENSION INP(12),PROC(3),CAP(3),SUM(4), GVOL(3),EMISB(3),
     2EMISA(3),EM1(2),COST(2),EMU(3)
      COMMON GVPPT,EQUIP,EQCOST,ADCOST,SIZE
      NS = 16
      IAGCR = 0
      ICODE = 0
      JNE = 1
      NE = 1
  8   COST(1) = 0.
      COST(2) = 0.
      EM1(1) = 0.
      EM1(2) = 0
C
C         READ IN KODE TO DETERMINE THE FOLLOWING:
C          KODE VALUE  PLANT DATA  CALL OUTFI
C          --------  ------------  ----------
C              0          YES          NO
C              1          YES          YES
C              2          NO           YES
C              3          NO           NO
      READ 610, KODE
C         IN THE ABSENCE OF ACTUAL PLANT CONFIGURATIONS A MODEL PLANT IS
C            ASSUMED WITH THE FOLLOWING SIZES FOR EACH PROCESS I.
      READ 611, (SIZE(I), I = 1,3)
      READ 611,(GVOL(I),I = 1,3)
      READ 611, (CEF1(I),I = 1,3)
      READ 611, (CEF2(I),I = 1,3)
      READ 611, (CFAC(I),I = 1,3)
      READ 611, (AFAC(I),I = 1,3)
C         * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C          CEF1(I) IS THE CONTROL EFFICIENCY FOR 1967 FOR PROCESS I.
C         CEF2(I) IS THE REQUIRED CONTROL EFFICIENCY FOR PROCESS TYPE I.
C        CFAC(I)=CAPITAL COST FACTOR ($1000/T/HR) FOR EACH PROCESS TYPE I
C        AFAC(I)=ANNUAL  COST FACTOR ($1000/T/HR) FOR EACH PROCESS TYPE I
C
 10   CONTINUE
      DO 11 I = 1,3
      CAP(I) = 0.
      EMISA(I) = 0.
      EMISB(I) = 0.
 11   EMU(I) = 0.
      DO 13 I = 1,2
      EM1(I) = 0.
 13   COST(I) = 0.
      READ 500,NC,RSAC,TOTCAP,(INP(I),I=1,12)
      IF(NC-9)12,800,12
 12   CONTINUE
C        TOTCAP INPUT IS IN THOSANDS OF TONS/YR.
C       REDUCE TOTCAP TO TONS/HR. AND COMPUTE NO. OF EACH PROCESS TYPE
C          OF MODEL SIZE BASED ON THE FOLLOWING
C           FLASH DRIER = RPOC(1) WITH MODEL SIZE OF  53 T/HR.
C           FLUID. BED  = PROC(2) WITH MODEL SIZE OF 208 T/HR.
C           PNEUMATIC   = PROC(3) WITH MODEL SIZE OF  70 T/HR.
      HRC= (TOTCAP *1000.0)/ 3750.0
      PROC(1)=0.565 * HRC * 0.207
      PROC(2)=0.435 * HRC * 0.207
      PROC(3)=0.071 * HRC
C        CAP(I) IS SIZE OF PROCESS TYPE I OTHER THAN MODEL SIZE. COSTS
C         ARE DETERMINED BY TABLE LOOK-UP AS A FUNCTION OF GAS FLOW.
      DO 60 I = 1,3
      IF(PROC(I)-SIZE(I))20,30,40
 20   CAP(I)= PROC(I)
      SAVE(I) = 0.
      GO TO 50
 30   SAVE(I) = PROC(I)
      GO TO 50
 40   ITEMP = PROC(I)/SIZE(I)
      TEMP = ITEMP
      CAP(I) = PROC(I) - TEMP*SIZE(I)
      SAVE(I)=TEMP* SIZE(I)
C        SAVE(I) IS MULTIPLES OF MODEL SIZE I.
 50   CONTINUE
      EQUIP(I) = 2.0
      GVPPT(I) = (GVOL(I) * CAP(I))/1000.
 60   CONTINUE
C        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C        COMPUTE EMISSIONS AND COSTS
C        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      CALL COSTED
      AOCOST(1) = 0.270 * GVPPT(1)**0.983 + 1.0
      AOCOST(2) = 0.371 * GVPPT(2)** 0.974 + 1.0
      AOCOST(3) = 0.270 * GVPPT(3)** 0.983 + 1.0
      DO 70 I = 1,3
      COSTI(I)= 2.5 * EQCOST(I) + SAVE(I) * CFAC(I)
      COSTYR(I)= 0.2 * COSTI(I) + AOCOST(I) + SAVE(I) * AFAC(I)
      COST(1) = COST(1) + COSTI(I)
 70   COST(2) = COST(2) + COSTYR(I)
      EMU(1)=(12. * PROC(1) * 3750.0)/2000.
      EMU(2) = (13. * PROC(2) * 3750.0)/2000.
      EMU(3)=( 3. * PROC(3) * 3750.0)/2000.
      DO 80 I = 1,3
      EMISB(I)=EMU(I) * (1.0 - CEF1(I))
      EMISA(I)=EMU(I) * (1.0 - CEF2(I))
      EM1(1) = EM1(1) + EMISB(I)
 80   EM1(2) = EM1(2) + EMISA(I)
      SUM(1) = SUM(1) + EM1(1)
      SUM(2) = SUM(2)+ EM1(2)
      SUM(3) = SUM(3)+ COST(1)
      SUM(4) = SUM(4) + COST(2)
 100  CONTINUE
      IF(KODE-1)200,210,220
 200  CONTINUE
C        PRINT PLANT DATA.
      PRINT 600,(INP(I),I=1,12),EM1(1),EM1(2),COST(1),COST(2)
      GO TO 10
```

```
  210 CONTINUE
      PRINT 600,(INP(I),I=1,12),EM1(1),EM1(2),COST(1),COST(2)
      IF(KODE - 3)220,250,250
  220 CONTINUE
      CALL OUTFI(RSAC,ICODE,IAQCR,NS,INP,COST,NE,JNE,EM1)
      GO TO 10
  250 CONTINUE
  800 CONTINUE
      PRINT 601,(SUM(I),I=1,4)
      IF(RSAC)820,810,820
  810 CONTINUE
      DO 811 I = 1,4
  811 SUM(I) = 0.
      GO TO 10
  820 CONTINUE
C       SUM(3) IS THE INVEST COST
C       SUM(4) IS THE ANNUAL COST
C       SUM(1) IS THE 1967 EMISSIONS
C       SUM(2) IS THE CONTROLLED EMISSIONS
  500 FORMAT (I2,3X,A4,F12.1,9X,12A4)
   600 FORMAT (2X,12A4,4F12.2)
  601 FORMAT(50X,4F12.2)
  610 FORMAT (I5)
  611 FORMAT (3F10.3)
      STOP
      END

      SUBROUTINE COSTEQ
C         THE PURPOSE OF THIS SUBROUTINE IS TO CONMPUTE COSTS OF
C         EQUIPMENT ($1000), EQCOST(I), AS A FUNCTION OF INLET
C         GAS VOLUME (1000 ACFM)), GVPPT(I), AND NUMBER OF EACH
C         EQUIPMENT REQUIRED, NUMB(I), FOR EACH PROCESS TYPE I.
C         THE FIRST THREE PROCESS TYPES ARE DESIGNATED AN EQUIPMENT TYPE,
C         EQUIP(I), AS FOLLOWS
C                 1 FOR 316 ELC STAINLESS STEEL
C                 2 FOR 304 VENTURI/MS CLS
C                 3 FOR ALL MILD STEEL
      REAL NUMB
      DIMENSION GVPPT(4),EQUIP(4),EQCOST(4),NUMB(4),ADCOST(4),
     2SIZE(4)
      COMMON GVPPT,EQUIP,EQCOST,ADCOST,SIZE
      DO 150 I=1,3
      NUMB(I) = 1.
      IF(GVPPT(I)-80.000)10,10,100
   10 IF(GVPPT(I)-4.000)12,12,50
   12 EXP = 0.3125
      IF(EQUIP(I)-2.0)20,30,40
   20 A = 3.5
      GO TO 150
   30 A = 2.9
      GO TO 150
   40 A = 2.2
      GO TO 150
   50 IF(EQUIP(I) -2.0)60,70,80
   60 A = 2.4
   62 EXP = 0.59375
      GO TO 150
   70 A = 2.0
      GO TO 62
```

```
80    A = 1.6
      EXP = 0.53125
      GO TO 150
100   EXP = 0.812
      IF(EQUIP(I)-2.0)110,120,130
110   A = 3.5
      GO TO 150
120   A = 2.9
      GO TO 150
130   A = 2.2
      GO TO 150
150   EQCOST(I) =(A*GVPPT(I)** EXP)*NUMB(I)
      RETURN
      END
```

```
 INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS:


   0
  50.000   208.000    70.000
 540.000   480.000   357.000
     700      .700      .130
     932      .978      .800
     463      .247      .316
     219      .201      .148
```

# APPENDIX F

## Computer Program for Cement

## Appendix F

## Computer Program for Cement

### I. INTRODUCTION

The portland cement industry produces cement by the wet or dry process, distinguished by whether the kiln is fed with wet or dry material. In general, the emissions and costs of emission control are different for the two types of processes.

Data for the cement industry was irregular; some had individual kiln sizes and types (wet or dry) while others had only plant capacity and type. However, since process type was always known, data for each plant are presented in the detailed format. Figure F-1 shows a flow chart of the computer program logic.

The remainder of this appendix is organized as follows: Section II lists the assumptions on which the program is based; Section III describes the actual program operations; Section IV is a Glossary of the FORTRAN names used in the program; and Section V contains an actual program listing, followed by the fixed parameters used in this report.

### II. ASSUMPTIONS

The assumptions on which the computer program operations are based are:

a) Particulates are the only emissions requiring control.

b) Some plants adequately controlled particulate emissions in 1967. (Identified as 99% controlled.)

c) Although full costs are assigned, some plants in 1967 partially controlled particulate emissions with primary collectors.

d) There are two distinct process types--wet and dry.

e) Costs can be accurately assigned using linear interpolation.

Parameters on which the costs and emissions for this report are based are listed at the end of Section V and identified in Table F-1.

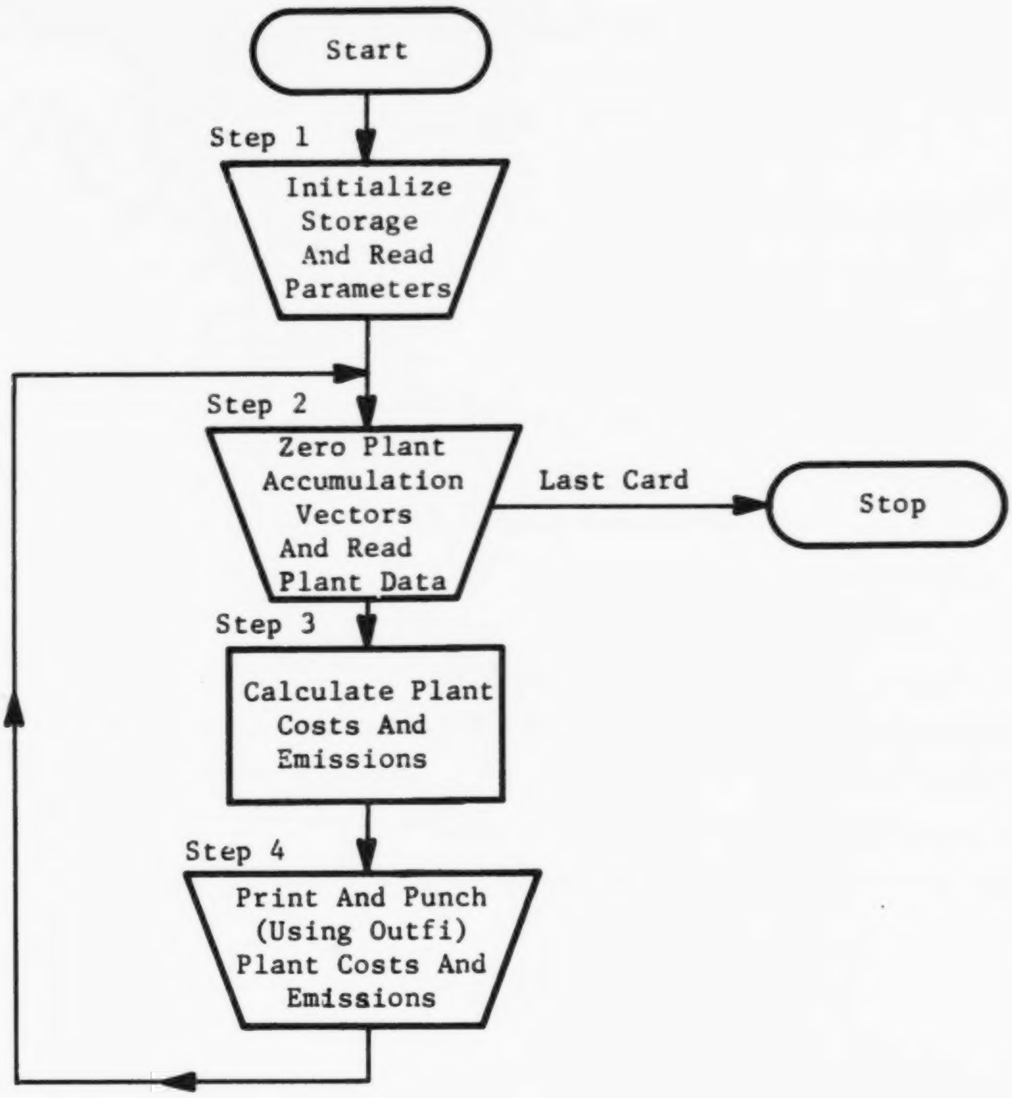

Start
Step 1
Initialize Storage And Read Parameters
Step 2
Zero Plant Accumulation Vectors And Read Plant Data
Last Card
Stop
Step 3
Calculate Plant Costs And Emissions
Step 4
Print And Punch (Using Outfi) Plant Costs And Emissions

Fig. F-1. - Flow Chart for the Cement Computer Program.

## TABLE F-1. - LIST OF PARAMETERS FOR PROGRAM CEMENT

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1-3 | | |
| REFF(2,11) | Table of required control efficiencies for (1) dry and (2) wet processes. Entries correspond to capacities in RC (see below). | 1-80<br>1-80<br>1-16 | 10F8.0<br>10F8.0<br>2F8.0 |
| | Cards 3-8 | 17-80 | 8F8.0 |
| RC(5,11) | Capacities (row 1), investment (rows 2 and 3) and annualized costs (rows 4 and 5) for dry (rows 2 and 4) and wet (rows 3 and 5) processes. | 1-80<br>1-80<br>1-80<br>1-80<br>1-56 | 10F8.0<br>10F8.0<br>10F8.0<br>10F8.0<br>7F8.0 |
| | Card 8 | | |
| EFACT(2) | Emission factors for (1) dry and (2) wet processes. | 57-72 | 2F8.0 |

## III. PROGRAM OPERATIONS

Step numbers refer to the flow chart in Figure F-1.

Step 1.

Storage is initialized and parameters are read in. See Table F-1 and the end of Section V for these parameters.

Step 2.

Accumulation vectors for plant costs and emissions (C1 and E1) are set to zero. Data for one plant are read in as detailed in Table F-2.

Step 3.

Costs and emissions are calculated and accumulated for the plant. A table lookup is used for determining the costs, uncontrolled emissions, and 1967 and required control efficiencies. A key of 99 percent 1967 control efficiency was used to show that adequate controls existed in 1967, even though this is less than the required control efficiency by a few tenths of a percent. In this case, the 1967 and final emissions are the same. If the 1967 control efficiency is less than 99%, the lower value is used in calculating 1967 emissions; no cost credits are allowed, however.

Step 4.

Costs, emissions, plant name and plant location are printed and punched. Subroutine OUTFI is used to punch the output.

Control is transferred to Step 2. When the last card is read the program stops.

TABLE F-2. - LIST OF PLANT INPUT DATA

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card Type 1 | | |
| | Blank | 1 | 1X |
| ICODE | Card type identification. | 2 | I1 |
| JAUX | Input type identification (not needed). | 3 | I1 |
| SCODE_ | Industry code (14 for cement). | 4-5 | F2.0 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| TOTCAP | Total plant capacity | 11-20 | F10.0 |
| NPROC | Number of separate unit processes described on cards type 2. | 21-22 | I2 |
| | Blanks | 23-30 | 8X |
| INPUT(12) | Plant name and location. | 31-78 | 12A4 |
| | Card Type 2 | | |
| | Same as card type 1 for card columns 1-10. | | |
| IUNIT(2,10) | Data storage for (1) unit type and (2) number of units, of each of up to 10 different unit processes. | row 1: 11-12, 31-32<br>row 2: 13-15, 33-35 53-55 | I2<br>I3 |
| EFF(10) | Efficiency of control for 1967. | 16-17, 36-37, 56-57 | F2.0 |
| CAP(10) | Unit process capacity | 18-25, 38-45, 58-65 | F8.0 |
| | Blanks | 26-30, 45-50, 65-70 | 5X |

# IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| C1(2) | Vector for accumulation of (1) investment and (2) annualized costs for entire plant. |
| CAP(10) | Unit process capacity storage (see Table F-2). |
| CC | Temporary variable. |
| DEL | Interpolation fraction. |
| E1(2) | Vector for accumulation of (1) 1967 and (2) controlled plant emissions. |
| EFACT(2) | Emission factors (see Table F-1). |
| EFF(10) | Unit process control efficiencies for 1967 (see Table F-2). |
| FACT | Temporary variable. |
| I | Indexing variable. |
| IA | Temporary variable. |
| IB | Variable for table indexing. |
| EC | Variable for table indexing. |
| ICODE | Card type identification. |
| INPUT(12) | See Table F-2. |
| IUNIT(2,10) | See Table F-2. |
| J | Indexing variable. |
| JAUX | Dummy variable. |
| OUTFI | Standard punched output subroutine. |
| RC(5,11) | Costs table (see Table F-1). |
| REFF(2,11) | Required efficiency table (see Table F-1). |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |
| SCODE | Industry code (14 for cement). |

## V. LISTING OF THE COMPUTER PROGRAM FOR CEMENT

```
C     PROGRAM CEMENT
C     THIS PROGRAM CALCULATES CONTROL COSTS AND EMISSIONS FOR CEMENT.
C
C     TWO PROCESSES0 DRY (1) AND WET (2).  DRY CONTROLLED BY ESP, WET BY
C     FF.
C     CREDITS GIVEN FOR CONTROLS INSTALLED WITH MORE THAN 85( EFFICIENCY.
C
      DIMENSION C1(2), E1(2), CAP(10), IUNIT(2,10), EFF(10), INPUT(12),
     1 RC(5,11), EFACT(2), REFF(2,11)
C
C     INITIALIZE.  CFACT IS FOR CONVERSION TO TONS/HR.
C
      DO 10 I=1,10
      CAP(I)=0.
      EFF(I)=0.
      DO 10 J=1,2
      IUNIT(J,I)=0
   10 CONTINUE
      READ 4999, REFF, RC, EFACT
 4999 FORMAT(10F8.0)
C
C     READ 1 CARD.
C
   20 READ 5000, ICODE, JAUX, SCODE, RSAC1, RSAC2, TOTCAR, NPROC, INPUT
 5000 FORMAT(1X,2I1,F2 0,A4,A1,F10.0,I2,8X,12A4)
      IF (ICODE-1) 2000,30,1000
   30 IF (SCODE-14.) 1010,40,1010
C
C     READ DETAILED DATA
C
   40 READ 5005, ICODE, SCODE,((IUNIT(J,I),J=1,2),EFF(I),CAP(I),I=1,
     1 NPROC)
 5005 FORMAT(1X,I1,1X,F2.0,5X,3(I2,I3,F2.0,F8.0,5X),/,(10X,I2,I3,F2.0,
     1 F8.0,5X,I2,I3,F2.0,F8.0,5X,I2,I3,F2.0,F8.0))
      IF (ICODE-2) 1020,50,1020
   50 IF (SCODE-14.) 1010,90,1010
C
C     CONVERT BBL/DAY TO TONS/HR.
C
   90 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      DO 190 I=1,NPROC
  100 IA=IUNIT(1,I)
      FACT=IUNIT(2,I)
      CC=CAP(I)
  110 IF (CC-5.4) 130,130,120
  120 FACT=FACT*2.
      CC=CC/2.
      GO TO 110
  130 DO 160 J=2,11
      IF (CC-RC(1,J)) 140,150,160
  140 IB=IA+1
      IC=IA+3
      DEL=   (RC(1,J)-BC)/(RC(1,J)-RC(1,J-1))
      GO TO 170
  150 DEL=0.
      IB=IA+1
      IC=IA+3
      GO TO 170
  160 CONTINUE
      GO TO 110
  170 IF (EFF(I)-99.) 171,180,180
  171 C1(1)=C1(1)+(DEL*(RC(IB,J-1)-RC(IB,J))+RC(IB,J))*FACT
      C1(2)=C1(2)+(DEL*(RC(IC,J-1)-RC(IC,J))+RC(IC,J))*FACT
  180 E1(1)=E1(1)+EFACT(IA)*CC*FACT*(1.-EFF(I)/100.)
      E1(2)=E1(2)+EFACT(IA)*CC*FACT*(1 -(REFF(IA,J-1)-REFF(IA,J))*DEL-
     1 REFF(IA,J))
  190 CONTINUE
      CALL OUTFI(RSAC1,RSAC2,AQCR,14,INPUT,C1,1,1,E1)
      PRINT 5555, INPUT, C1, E1
 5555 FORMAT(1X,12A4,4F15.2)
      GO TO 20
C
C   ERROR ROUTINES
C
 1000 PRINT 5025, ICODE
 5025 FORMAT(19H INVALID CARD CODE,,I4  ,34H 1 EXPECTED.  SKIP TO NEXT 1
     1 CARD.)
      GO TO 20
 1010 PRINT 5030, SCODE
 5030 FORMAT(21H INVALID SOURCE CODE ,F4.2,23H.  SKIP TO NEXT 1 CARD.)
      GO TO 20
 1020 PRINT 5040, ICODE
 5040 FORMAT(19H INVALID CARD CODE ,I4  ,23H.  SKIP TO NEXT 1 CARD.)
      GO TO 20
C
C   OUTPUT ROUTINE.  EACH CARD READ IN IS PRINTED, AND CUMULATIVE TOTALS
C   FINAL OUTPUT.
C
 2000 PRINT 5045
 5045 FORMAT(12H1GOOD FINISH)
      STOP
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

```
   .90      .90     .95      .95     .978     .976     .984     .982     .995     .993
  .996     .994    .998     .996     .999     .998    .9994     .999    .9996    .9994
  9997    .9996      0.      39.     140.      10.      28.      .15      49.     174.
   13.      35.       3      78.     210.      22.      44.      .60     148.     296.
   40.      53.     1 2     280.     408.      70.      90.      1.8     388.     612.
  111.     134.     2 4     525.     782.     150.     173.      3.0     665.     952.
  189.     211.     3 6     840.    1088.     235.     241.      4.5    1015.    1296.
  287.     289.     5 4    1175.    1475.     334.     330.   15040.   12950.
```

# APPENDIX G

## Computer Program for Grain Handling and Milling

# Appendix G

## Computer Program for Grain Handling and Milling

### I. INTRODUCTION

Grain mills and elevators emit particulate emissions through milling of animal feeds and the storage and handling of grains.

The purpose of this report is to describe a computer program designed to compute the emissions and associated costs for controlling the emissions inherent to the grain milling and handling industry. The available data base consists of only the scope and location of the plant. Therefore, the program was tested with trial data. A general flow diagram of the program logic is shown in Figure G-1.

Section II presents the major assumptions and limitations in the program; Section III explains the program logic with tables of input data formats; Section IV is a glossary of FORTRAN names; and Section V is a listing of the computer program and the control data.

### II. MAJOR ASSUMPTIONS AND LIMITATIONS

The major assumptions made in regard to the calculations of emissions and costs for the computer program area as follows:

a) For purposes of installing baghouses, it was assumed that all elevators have volume capacities greater than 10,000 bushels.

b) The program dimension statement limits each mill to 20 elevators.

### III. PROGRAM OPERATIONS

This program computes the emission of particulates, EM1(I), both before and after added controls. These particulates are generated in both the milling process of animal feed and in handling and cleaning of grains in elevators. If the facility is for grain storage only, the computer program by-passes steps 3 and 4 below. This is indicated when the capacity of the mill, TOTCHP, is zero.

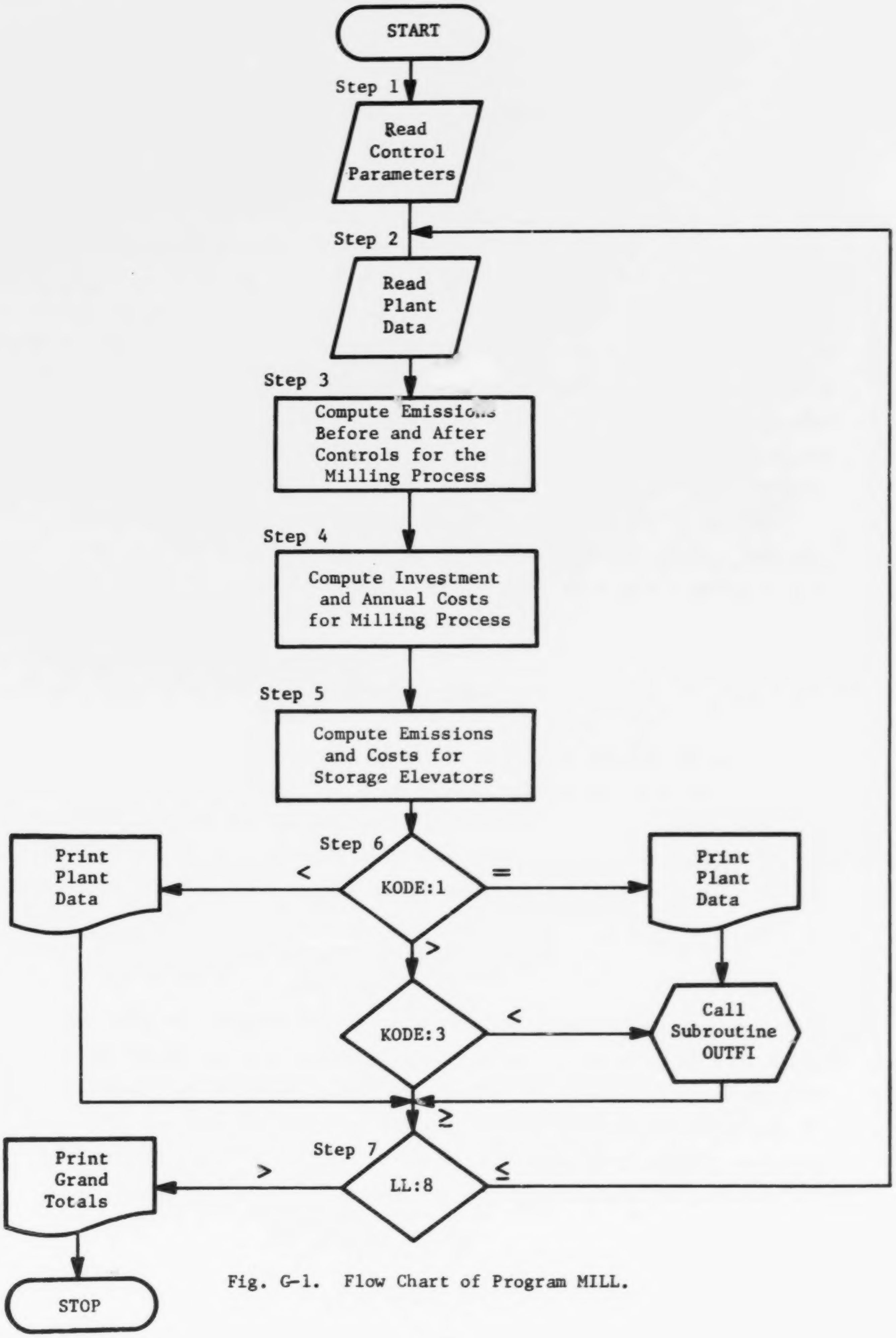

START
Step 1
Read Control Parameters
Step 2
Read Plant Data
Step 3
Compute Emissions Before and After Controls for the Milling Process
Step 4
Compute Investment and Annual Costs for Milling Process
Step 5
Compute Emissions and Costs for Storage Elevators
Step 6
KODE:1
<
=
>
Print Plant Data
Print Plant Data
KODE:3
<
Call Subroutine OUTFI
≥
Step 7
LL:8
>
≤
Print Grand Totals
STOP

Fig. G-1. Flow Chart of Program MILL.

Step 1.

The initial step in the program is the input control parameters and the initialization of variables.

Step 2.

This is the beginning of a loop which reads in individual plant data and consists of at least two data cards. If the total number of elevators is greater than six, another data card is required for each additional six elevators. A description of the input data with formats is given in Table G-1.

Step 3.

The annual production, PROD, in tons is computed next in order to compute the daily capacity, DCAP, in tons/day. Using the annual production computed, the controlled emissions, EM1(2), are computed assuming a 99 percent control level. The emission rates are dependent on present controls, assuming a 70 percent control for cyclones and a 99 percent control for baghouses. The controls are determined by an input variable ICONT.

Step 4.

The investment costs for milling controls are functions of daily capacity, DCAP, in tons per day. The minimum investment cost for a baghouse is 10 thousand dollars. The minimum daily capacity for all mills is 90 tons per day. If the daily capacity is between 90 and 800 tons per day the investment cost is computed as follows:

$$\mathrm{CO1(1)} = 0.029 \times (\mathrm{DCAP} + 150.0)^{1.0625} .$$

If the daily capacity is greater than 800 tons per day the investment cost is:

$$\mathrm{CO1(1)} = 0.036 \times \mathrm{DCAP}^{1.0625} .$$

The annual operating costs are computed as 35 percent of the investment cost. There are no costs if the mill already has baghouses.

Step 5.

The program goes through a loop once for each elevator, looping a total of NEL times in order to compute the present emissions and investment costs for all elevators. This is accomplished by first computing the uncontrolled emissions for each elevator based on size. The present

TABLE G-1. - CONTROL PARAMETERS AND PLANT DATA FOR PROGRAM MILL

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 (Control Parameter) | | |
| KODE | Denotes when to print plant data and/or when to call Subroutine OUTFI. | 1-5 | I5 |
| | Card 1 (Plant Data) | | |
| NCO | Card 1. | 1-2 | I2 |
| NS | Assigned source number. | 3-5 | I3 |
| RSAC | National location code. | 6-9 | A4 |
| ICONT | Control to denote the type of control for milling as follows: 0 for no control, 1 for cyclone separator, 2 for baghouse, and 3 for both cyclone separator and baghouse. | 10 | I1 |
| TOTCAP | Annual capacity of mill, 1000 tons. | 11-20 | F10.3 |
| PCTP | Percentile of total capacity which is production. | 21-24 | F4.2 |
| DAYS | Number of days per year mill is operated. | 25-30 | F6.0 |
| INP(I) | Name and location of mill. | 31-78 | 12A4 |
| | Card 2 (Plant Data) | | |
| NCO | Card 2. | 1-2 | I2 |
| NEL | Total numberof elevators. | 3-4 | I2 |
| | Blank. | 5-10 | 6X |
| KONT(I) | Control for elevator I same as ICONT. | 11-12 | I3 |
| CAP(I) | Capacity of elevator I, 1000 bu. | 18-25 | F8.0 |
| | Blank . | 26-30 | 5X |
| | Same as card columns 11 through 30 above with I=2. | 31-50 | |
| | Same as card columns 11 through 30 above with I=3. | 51-70 | |
| LL | A "7" in this space indicates the end of data for the current plant. A "9" denotes the last data card for the last plant and grand totals are printed out. | 71-72 | I2 |

emissions are then determined according to the type of control on the elevator as denoted by KONT(I). The investment cost is computed analytically as a function of elevator size. If the capacity of the elevator is less than 10 thousand bushels the cost is a flat 10 thousand dollars. From 10 to 100 thousand bushels the cost is computed analytically as follows:

$$CO1(1) = CO1(1) + 0.07 \times CAP(I)^{1.125} .$$

If the capacity is greater than 100 thousand bushels the cost is:

$$CO1(1) = CO1(1) + 0.113 \times CAP(I).$$

This ends the elevator loop. The annual operating cost, CO1(2), is 35 percent of the investment cost.

The emissions and costs are then added to the running summations in order to output grand totals.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program is explained in Appendix V.

Step 7.

The program checks the 3rd plant data card for an "8" or a "9" punched in LL (Column 72). If the value for LL is "8," the program returns control to Step 3 where the process is resumed with subsequent plants until a "9" appears in the "LL" column. When the value for LL is "9," the program prints the total costs and emissions if applicable and terminates.

## IV. GLOSSARY OF FORTRAN NAMES FOR PROGRAM MILL

| FORTRAN Name | Definition |
|---|---|
| CAP(20) | Volume capacity (1000 Bu.) of elevator I. |
| COST(2) | Aggregated investment and annual costs. |
| CO1(2) | Investment and annual cost of controlling emissions for a given plant. |
| DAYS | Number of days per year a plant is operative. |
| DCAP | Daily capacity of a plant in tons/day. |
| EMIS(2) | Sum of present and controlled emissions for a number of plants. |
| EMU | Uncontrolled emissions (tons/yr) for a given plant. |
| EM1(2) | Present and controlled emissions (tons/yr) for a given plant. |
| ICODE | Dummy variable used in calling subroutine OUTFI. |
| ICONT | Code to denote the milling controls as follows: 0 for no controls, 1 for cyclone, 2 for baghouse, and 3 for both cyclone and baghouse. |
| INP(11) | Name and address of feed mill. |
| IAQ | Dummy variable for Subroutine OUTFI. |
| KODE | Code to determine when to output plant data and/or to bypass Subroutine OUTFI. |
| KONT | Denotes the controls on storage elevators in same way as ICONT does for milling. |
| NCO | Number or type of data card. |
| NE | Number of emissions for source. |
| NEL | Number of elevators in a given mill. |
| NPLT | Plant number in sequential order of input. |
| NS | Arbitrary number assigned to source. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| PCTP | Percentile of total annual capacity which is production. |
| PROD | Annual production. |
| NSAC | National location code. |
| SUM(4) | Sum of emissions and costs for grand total output. |
| TOTCAP | Annual capacity of mill (1000 tons) |
| LL | Code to determine end of data for a given plant and also end of data for all plants. Also used to determine when totals are printed out. |

## V. LISTING OF THE COMPUTER PROGRAM FOR GRAIN MILLING AND HANDLING

```
      PROGRAM MILL
C        THIS PROGRAM COMPUTES EMISSIONS AND CONTROL COSTS FOR FEED
C           MILLS. THE EMISSIONS BEFORE AND AFTER CONTROLS ARE EM1(I).
C
      INTEGER RSAC
      DIMENSION INP(12),KONT(20),         CAP(20),EM1(2),CO1(2),COST(2),
     2EMIS(2),SUM(4)
C          ICONT DENOTES THE CONTROL FOR MILLING AS FOLLOWS  0 FOR NONE,
C            1 FOR CYCLONE  2 FOR BAGHOUSE, AND 3 FOR BOTH.
C         PCT IS THE THROUGHPUT AS A PERCENTILE OF CAP.
C         CAP IS THE VOLUME OF CAPACITY (1000 BU.) OF ELEVATOR.
C         KONT(I) DENOTES THE CONTROL FOR STORAGE SAME AS ICONT ABOVE.
C                ASSUME NOT MORE THAN 3 ELEVATORS PER MILL
      NPLT = 0
      NE = 1
      ICODE = 0
      IAQ = 0
      PRINT 580
      PRINT 590
      PRINT 591
      READ 600, KODE
 10   CONTINUE
      NPLT = NPLT +1
      M = 1
      N = 6
      DO 11 I = 1,2
      CO1(I) = 0.
 11   EM1(I) = 0.
C     TOTCAP IS THE ANNUAL CAPACITY OF THE MILL IN THOUSANDS OF TONS.
C        PCTP IS THE PERCENTILE OF TOTAL CAPACITY WHICH IS PRODUCTION.
C        DAYS IS THE NUMBER OF DAYS/YEAR THE MILL IS IN OPERATION.
C
      READ 630, NCO, NS, RSAC, ICONT, TOTCAP,PCTP,DAYS,(INP(I),I=1,12)
 12   READ 650,NCO,NEL,(KONT(I),CAP(I),I =M,N),LL
      IF(NEL-N)15,16,14
 14   N = N + 6
      M = M + 6
      GO TO 12
 16   CONTINUE
      IF(TOTCAP)50,50,161
 161  CONTINUE
C        COMPUTE THE DAILY CAPACITY, DCAP, IN TONS/DAY.
C
      PROD = TOTCAP * PCTP * 1000
      DCAP = PROD/DAYS
C     COMPUTE THE EMISSIONS AND COSTS FOR THE MILLING PROCESS
C
      EM1(2) = 0.18 * PROD
      IF(ICONT-1)17,18,40
 17   EM1(1) = 18.0 * PROD
      GO TO 20
 18   EM1(1) = 5.4 * PROD
 20   IF(DCAP-90.0)22,24,24
```

```
   22 C01(1) = 10.
      GO TO 50
   24 IF(DCAP - 300.)26,26,30
   26 C01(1) = 0.029 * (DCAP + 150.0) **1.0625
      GO TO 50
   30 C01(1) = 0.036 * DCAP **1.0625
      GO TO 50
   40 EM1(1) = 0.16* PROD
   50 CONTINUE
C        COMPUTE THE EMISSIONS AND COSTS FOR STORAGE
      DO 200 I = 1, NEL
      IF(CAP(I)-375.0)110,110,120
  110 EMU =(250.0 *CAP(I)) /2000.0
      GO TO 130
  120 EMU = (1600. *CAP(I))/2000.
  130 CONTINUE
      IF(KONT(I)-1)140,150,160
  140 EM1(1)= EM1(1) + EMU
      GO TO 151
  150 EM1(1) = EM1(1) + 0.30* EMU
  151 IF(CAP(I)-10.0)152,154,154
  152 CAP(I) = 10.0
      GO TO 156
  154 IF(CAP(I) - 100.0)156,156,158
  156 C01(1) = C01(1) + 0.07 * CAP(I) **1.125
      GO TO 180
  158 C01(1) = C01(1) + 0.113 * CAP(I)
      GO TO 180
  160 IF(KONT(I)-2)180,170,170
  170 EM1(1) = EM1(1) + .01 * EMU
  180 EM1(2) = EM1(2) + .01 * EMU
  200 CONTINUE
      DO 210 J = 1,2
  210 EM1(J) = EM1(J) / 1000
      C01(2) = 0.35 * C01(1) + C01(2)
C        AGGREGATE EMISSIONS AND COSTS FOR GRAND TOTALS.
      COST(1) = COST(1) + C01(1)
      COST(2) = COST(2) + C01(2)
      EMIS(1) = EMIS(1) + EM1(1)
      EMIS(2) =EMIS(2) + EM1(2)
      SUM(1) = SUM(1) +EM1(1)
      SUM(2) = SUM(2) + EM1(2)
      SUM(3) = SUM(3) + C01(1)
      SUM(4) = SUM(4) + C01(2)
      IF(KODE -1)300,310,350
  300 CONTINUE
C        PRINT PLANT DATA.
      PRINT 760, NPLT,(INP(I),I =1,12),EM1(1),EM1(2),C01(1),C01(2)
      GO TO 400
  310 CONTINUE
      PRINT 760, NPLT,(INP(I),I =1,12),EM1(1),EM1(2),C01(1),C01(2)
  350 CONTINUE
      IF(KODE-3)360,400,400
  360 CONTINUE
      CALL OUTFI (RSAC,ICODE,IAQ,NS,INP,C01,NE,1,EM1)
  400 CONTINUE
C        PRINT GRAND TOTALS AND END PROGRAM IF LL IS GREATER THAN 8.
      IF(LL-8)10,402,402
  402 CONTINUE
```

```
      PRINT 770, EMIS(1),EMIS(2),COST(1),COST(2)
      DO 410 I =1,2
      EMIS(I) = 0.
 410  COST(I) =0.
      IF(LL-9)10,420,420
 420  CONTINUE
      PRINT 770,(SUM(I),I =1,4)
 580  FORMAT (47X,22H GTAIN MILLING PLANTS ,/35X,50HESTIMATES OF EMISSIO
     2N LEVELS AND ASSOCIATED COSTS ,//)
 590  FORMAT ( 6H PLANT,44X,                          52 HEMISSION LEVEL (1
     2000 TONS/YEAR INVESTMENT   ANNUAL  )
 591  FORMAT (33H  NO.  NAME AND LOCATION OF PLANT,17X,52HPRESENT
     2 CONTROLLED    COST($1000) COST($1000),//)
 600  FORMAT (I5)
 630  FORMAT (I2,I3,A4,I1,F10.3,F4.2,F6.0,12A4)
 650  FORMAT (2I2,6X,6(I2,F8.0),I2)
 760  FORMAT (I3,2X,12A4,4F12.2)
 770  FORMAT (23H TOTALS FOR ALL MILLS  ,30X,4F12.2)
      STOP
      END
```

```
INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS:

   0
```

# APPENDIX H

# Computer Program for Gray Iron Foundries

# Appendix H

## Computer Program for Gray Iron Foundries

## I. INTRODUCTION

The gray iron foundry industry contributes to air pollution by emitting particulates and carbon monoxide. The computer program, explained herein, is designed to compute those emissions and the associated costs for controlling the emissions.

The data base used in accessing the emissions and control costs for the gray iron foundry industry was obtained from a postcard survey of 1,681 foundries. This is not quite an ideal data base since the sizes of the cupolas are not given; therefore an average size was assumed. A general flow diagram of the program logic is shown in Figure H-1.

Section II of this appendix gives the major assumptions made in regard to the calculations of the emissions and costs. Section III explains the program logic giving tables of input data with formats. Section IV is a glossary of FORTRAN names and Section V is a listing of the computer program and the input data other than plant data.

## II. MAJOR ASSUMPTIONS

The following assumptions were made in regard to the calculations of emissions and control costs for the gray iron foundry industry:

a) Average control systems costs were used to estimate investment and annual costs for control of cupola emissions.

b) One emission control system is required for a pair of cupolas.

c) The emission of pollutants from electric arc and electric induction furnaces are nil in comparison to cupolas and therefore are omitted from this analysis.

d) Production is based on value of gray iron castings and the ratio of national value of shipments to the national production.

e) Capacities of all cupolas are assumed to be equal.

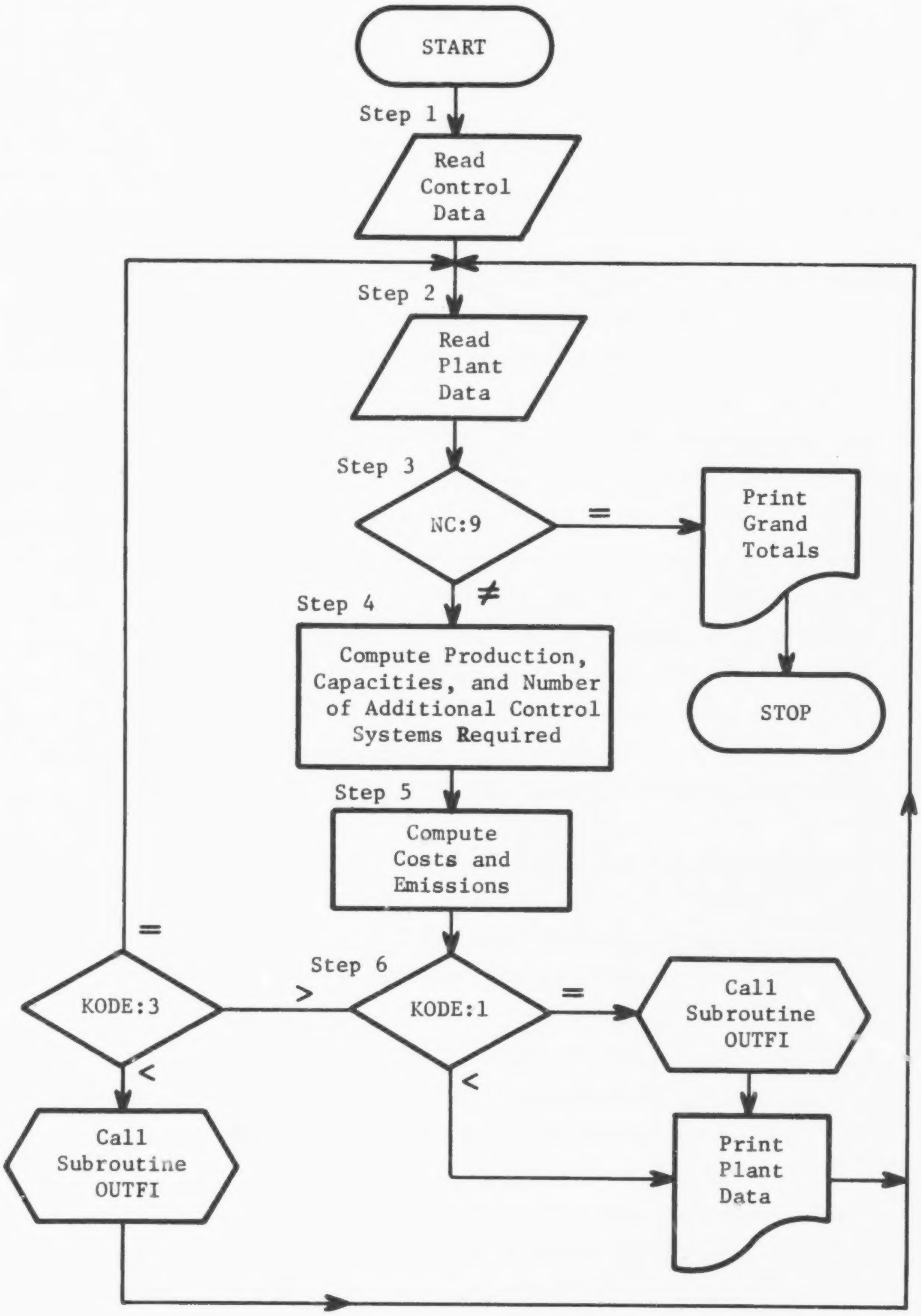

START
Step 1
Read Control Data
Step 2
Read Plant Data
Step 3
NC:9
=
Print Grand Totals
STOP
≠
Step 4
Compute Production, Capacities, and Number of Additional Control Systems Required
Step 5
Compute Costs and Emissions
Step 6
KODE:1
=
Call Subroutine OUTFI
<
Print Plant Data
>
KODE:3
=
<
Call Subroutine OUTFI

Fig. H-1. Flow Chart of Program GIRON.

f) All existing control systems are assumed to be equally effective.

g) One control system is required for every two cupolas.

## III. PROGRAM LOGIC

The logic in this computer program assumes a near ideal data base consisting of plant number, the number of cupolas, and type of emission controls presently installed at the plant. The cupola capacity is not available at this time; therefore, when and if it becomes available the program will require a few modifications. Also, there are some discrepancies in the data involving the number of cupolas and the value of gray iron costings which cause unrealistic answers. This occurs so infrequently that no attempt was made to program around this or to compute average values in the absence of data, i.e., either number of cupolas or value of gray iron costings.

The emissions before added controls are based on the capacities of the cupolas, XCUP, which is zero when the number of cupolas, NCUP, is zero. The controlled emissions are based on total production only, which is a function of the value of the gray iron costings, VALUE. Therefore, in the absence of either VALUE or NCUP, the computed emissions for a given plant may look unreasonable.

Step 1.

Only one control parameter, KODE, is input as datum in this program. The format for this card is shown in Table H-1. The purpose of this control parameter is explained in Step 6.

Step 2.

One card per plant is required to input the plant data as shown in Table H-1.

Step 3.

Immediately after the plant data are read in, the program checks the value of "NC" for a 9, in which case the grand totals are printed out and the program is terminated.

Step 4.

The production is estimated by dividing the value of the gray iron castings by the ratio of the value of national shipments to the national production. The total plant capacity is then estimated by dividing this number by 0.8. The capacity of each cupola is then computed in thousands of tons per year.

The number of control systems required is computed and checked against the number of existing systems to determine the number of additional systems needed.

Step 5.

Control costs are computed analytically as a function of cupola size, YC, and the number of systems required.

The emissions before added controls are computed as follows:

$$EM1(1) = EMU1\ (0.88X1 + 0.1X2)\ ,\ \text{and}$$
$$EM4(1) = EMU4\ (0.88X1 + 0.05X2)\ .$$

EMU1 and EMU4 are the uncontrolled emissions in tons. X1 and X2 are the number of uncontrolled and controlled cupolas, respectively. The control efficiency of uncontrolled cupolas is 12 percent for both particulates and carbon monoxide as indicated by the 0.88 in the above formula. The control efficiencies for controlled cupolas is 90 percent for particulates and 95 percent for carbon monoxide.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

## TABLE H-1. - INPUT DATA FOR THE GRAY IRON COMPUTER PROGRAM

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Denotes when to bypass Subroutine OUTFI and/or when to print plant data. | 1-5 | I5 |
| | Card 2 | | |
| NC | Card number. | 1-2 | I2 |
| NS | Source number. | 3-5 | I3 |
| RSAC | National location code. | 6-9 | A4 |
| | Blank. | 10 | X |
| VALUE | Value of gray iron castings, ($1000). | 11-20 | F10.2 |
| NCUP | Number of cupolas at plant. | 21-22 | I2 |
| ICS(1) | Code to denote presence of an electrostatic precipitator. | 23 | I1 |
| ICS(2) | Code to denote presence of a mechanical collector. | 24 | I1 |
| ICS(3) | Code to denote presence of a fabric filter. | 25 | I1 |
| ICS(4) | Code to denote presence of a wet scrubber. | 26 | I1 |
| ICS(5) | Code to denote presence of a wet cap. | 27 | I1 |
| ICS(6) | Code to denote presence of other controls. | 28 | I1 |
| | Blank. | 29-30 | ZX |
| INP(I), I=1,12 | Name and location of plant. | 31-78 | 12A4 |

# IV. GLOSSARY OF FORTRAN NAMES USED IN COMPUTER PROGRAM FOR GRAY IRON FOUNDRIES

| FORTRAN Name | Definition |
|---|---|
| COST(2) | Investment and annual operating costs, $1000. |
| EM1(2) | Particulate emissions before and after controls, tons/year. |
| EM4(2) | Carbon monoxide emissions before and after controls, tons/year. |
| EMU1 | Particulate emissions, tons/year, without controls. |
| EMU4 | Carbon monoxide emissions, tons/year, without controls. |
| ICS(6) | Code to indicate type of furnace controls. |
| INP(12) | Name and location of plant. |
| ITEMP | Temporary storage location for number of control systems required. |
| KODE | Code to determine when to bypass Subroutine OUTFI and/or when to print plant data. |
| NC | Card number. |
| NCUP | Total number of cupolas in foundry. |
| NE | Number of emissions by type from source. |
| NEED | Number of additional control systems required. |
| NREQS | Total number of control systems required. |
| NS | Source number arbitrarily assigned. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| NSYS | Total number of control systems already installed at foundry. |
| ODD | Denotes presence of odd numbers of uncontrolled cupolas. |
| PCUP | Production of cupola, 1000 tons/year. |
| PROD | Production of charged metal, 1000 tons/year. |
| RSAC | National location code. |
| SUM | Running summation of emissions and costs for output of grand totals. |
| SYS | Number of control systems required for every pair of uncontrolled cupolas. |
| VALUE | Annual value of gray iron castings, $1000. |
| XCUP | Same as NCUP. (Real value) |
| X1 | Total number of uncontrolled cupolas. |
| X2 | Total number of controlled cupolas. |
| Y | Total plant capacity, 1000 tons/year. |
| YC | Cupola capacity, 1000 tons/year. |

## V. LISTING OF THE COMPUTER PROGRAM FOR GRAY IRON

```
C       PROGRAM GIRON
C       PROGRAM TO COMPUTE EMISSIONS AND CONTROL COSTS FOR THE
C           GRAY IRON FOUNDRIES

        DIMENSION EM1(2),EM4(2),COST(2),SUM(6),ICS(6),INP(12)
        DO 7 I = 1,6
 7      SUM(I) = 0
        NE = 2
        PRINT 590
 590    FORMAT (48X,21H GRAY IRON FOUNDARIES,//,10X,10HPLANT NAME,30X,
       260H  EM1(1)      EM1(2)      EM4(1)      EM4(2)      COST(1)  COST(2)   )
C           READ IN KODE TO DETERMINE THE FOLLOWING
C            KODE VALUE  PLANT DATA  CALL OUTFI
C            --------  ------------  ----------
C                0           YES           NO
C                1           YES           YES
C                2           NO            YES
C                3           NO            NO
        READ 610, KODE
C           INPUT FOR EACH PLANT CONSISTS OF THE FOLLOWING0
C             VALUE - VALUE OF GRAY IRON CASTINGS, THOUSANDS OF DOLLARS.
C             NCUP - NUMBER OF CUPOLAS.
C             ICS(I) - A "9" FOR THE I-TH VALUE DENOTES  THE FOLLOWING 0
C               I = 1 FOR ELECTROSTATIC PERCIPITATOR
C               I = 2 FOR MECHANICAL COLLECTORS
C               I = 3 FOR FABRIC FILTERS
C               I = 4 FOR WET SCRUBBERS
C               I = 5 FOR WET CAPS
C               I = 6 FOR OTHERS
 8      CONTINUE
        READ  510, NC,NS,RSAC,VALUE,NCUP,(ICS(I),I=1,6), (INP(I),I=1,12)
        IF(NC-9)9,100,9
 9      CONTINUE
C           PRODUCTION IS ESTIMATED ON BASIS OF THE NATIONAL PRODUCTION
C             (14.3 MILLION TONS) VALUE OF SHIPMENTS ($2.7 BILLION).
        PROD = VALUE/188 81
        ITEMP = NCUP/2
        ODD = 0.
        Y = PROD /0.8
        XCUP = NCUP
        YC = Y/XCUP
C           Y IS THE TOTAL PLANT CAPACITY, THOUSANDS OF TONS PER YEAR
C           PCUP IS THE ANNUAL PRODUCTION OF CUPOAL, 1000 TONS/YR.
        PCUP = PROD/XCUP
        IF(NCUP-2*ITEMP)10,10,20
 10     NREGS = ITEMP
        GO TO 30
 20     NREGS = ITEMP + 1
        ODD = 1.0
 30     CONTINUE
        NSYS = 0
        DO 36 I = 1,6
        IF(ICS(I)-9)36,34,36
 34     NSYS = NSYS + 1
 36   CONTINUE
      IF(NREQS-NSYS)50,50,40
 40   NEED = NREQS - NSYS
      IF(ODD-1.0)44,42,44
 42   SYS = NEED - 1
      GO TO 80
 44   SYS = NEED
      GO TO 80
 50   CONTINUE
      SYS = 0.
      ODD = 0.
 80   CONTINUE
C         COMPUTE THE COSTS AND EMISSIONS
C         NUMBER OF UNCONTROLLED CUPOLAS, X1, AND NUMBER OF CONTROLLED
C           CUPOLAS, X2
      X1 = 2.0 *SYS + ODD
      X2 = XCUP - X1
      EMU1 = (17.4*PCUP/0.6)/2000.
      EMU4 = (250.*PCUP/0.6)/2000
      EM1(1) = EMU1*(0.88 * X1 + 0.1 * X2)
      EM4(1) = EMU4*(0.82 * X1 + 0.05* X2)
      EM1(2) = (17.4*(PROD/0.6) * 0.1 )/2000.0
      EM4(2) =(250.0*(PROD/0.6) * .05 )/2000.0
      COST(1) = (5.73 * YC + 67.56) * (SYS + ODD/1.4)
      COST(2) = (1.735* YC + 20.356)* (SYS + ODD/1.4)
      SUM(1) = SUM(1) + EM1(1)
      SUM(2) = SUM(2) + EM1(2)
      SUM(3) = SUM(3) + EM4(1)
      SUM(4) = SUM(4) + EM4(2)
      SUM(5) = SUM(5) + COST(1)
      SUM(6) = SUM(6) + COST(2)
C         OUTPUT OF EMISSIONS IS IN THOUSANDS OF TONS/YEAR AND COSTS
C           ARE  IN THOUSANDS OF DOLLARS/YEAR.
      IF(KODE-1)200,210,220
 200  CONTINUE
C         PRINT PLANT DATA.
      PRINT 601, (INP(I),I=1,12),EM1(1),EM1(2),EM4(1),EM4(2),COST(1),
     2COST(2)
      GO TO 8
 210  CONTINUE
      PRINT 601, (INP(I),I=1,12),EM1(1),EM1(2),EM4(1),EM4(2),COST(1),
     2COST(2)
      IF(KODE - 3)220,250,250
 220  CONTINUE
      CALL OUTFI (RSAC,ICODE, 0 ,NS,INP,COST,NE,1,EM1,4,EM4)
      GO TO 8
 250  CONTINUE
 100  CONTINUE
      PRINT 602,(SUM(I),I= 1,6)
 510  FORMAT (I2,I3,A4,1X,F10.2,I2,6I1,2X,12A4)
 601  FORMAT (2X,12A4,6F10.4)
 602  FORMAT (50X,6F10.2)
 610  FORMAT (I5)
      STOP
      END

INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS

  0
```

# APPENDIX I

## Computer Program for Iron and Steel

# Appendix I

## Computer Program for Iron and Steel

### I. INTRODUCTION

The purpose of this appendix is to describe a computer program designed to compute the emissions and costs for controlling the emissions attributed to the iron and steel industry. Unit processes covered in the program are: open hearth furances (assumed oxygen lanced), oxygen furnaces, electric furnaces, sintering wind boxes, and sintering machine discharges. Identification numbers associated with each process and used in the program are 1, 2, 3, 4, 5, respectively. Particulate emissions are controlled for all five processes and equipment has been selected so that the required fluoride emission controls for processes 1, 2, and 3 are met with no further controls required. Figure I-1 shows a general flow diagram of the computer logic.

The rest of this appendix discusses the program in detail. Section II states the assumptions upon which the calculations are based; Section III gives a description of the actual program operations; Section IV is a glossary of the FORTRAN names used in the program; and Section V contains program listing along with the input parameters used to produce the results supplied to APCO.

### II. ASSUMPTIONS

The assumptions made in calculating costs and emissions which are incorporated in the program are:

a) costs of control of particulates can be represented as a function of the capacity of the particular process, namely cost = a x $(\text{capacity})^b + c_o$ where a, b, and $c_o$ depend upon the control device type and the process to be controlled;

b) since a, b, and $c_o$ are calculated for a particular control level, costs are scaled to the control level required by the process weight rate standard for varying process sizes

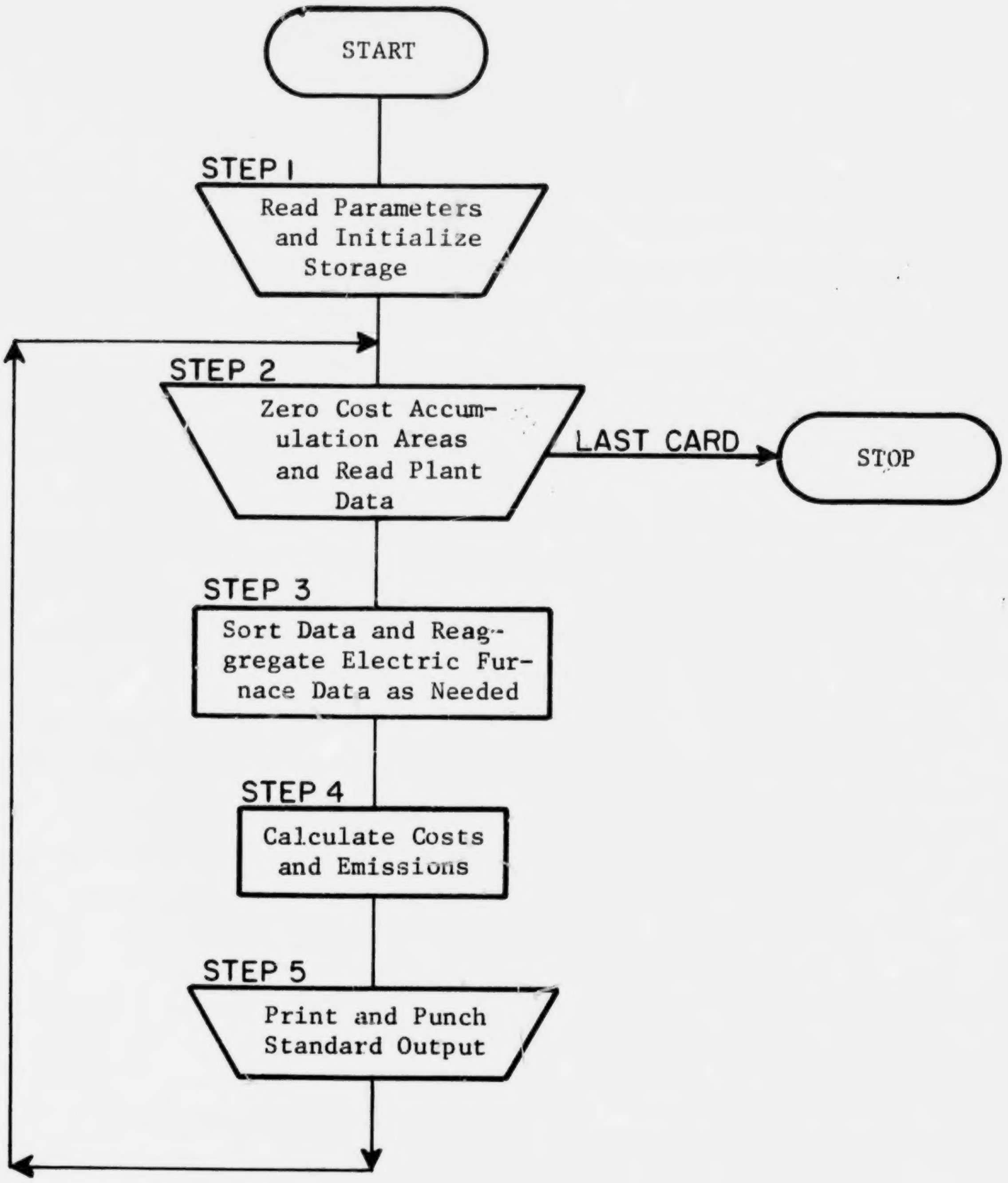

START
STEP 1
Read Parameters and Initialize Storage
STEP 2
Zero Cost Accumulation Areas and Read Plant Data
LAST CARD
STOP
STEP 3
Sort Data and Reaggregate Electric Furnace Data as Needed
STEP 4
Calculate Costs and Emissions
STEP 5
Print and Punch Standard Output

Fig. I-1. - Flow Chart for the Computer Program for Iron and Steel.

using logarithmic factors, and the control levels are generally based on the proposition that removing an additional 90 percent of residual emissions requires a doubling of both investment and annualized costs;

c) all unit processes which are currently controlled are assigned cost credits on the scale as described in (b), where control equipment is expected to be of the same type;

d) electric furnaces can be paired on a single control device with economic advantage if the capacity of the smaller is within 25 percent of the capacity of the larger; a single furnace system has control costs of 0.7143 of a "double furnace" system.

Costs and emissions presented in this report are based on:

a) control equipment costs from the Battelle Memorial Institute report Economic Aspects of Control of Air Quality in the Integrated Iron and Steel Industry, used to determine the various a, b, and $c_o$ (see Table 1 and Section V), with $c_o$ assumed to be zero;

b) plant location and detailed unit process data supplied by APCO for each plant.

c) the assumption that all basic oxygen process furnaces were adequately controlled when installed;

d) control levels required to meet the process weight rate emission standards for particulates.

## III. PROGRAM OPERATION

Step numbers refer to the flow chart in Figure I-1.

Step 1.

The program is initiated and the parameters are read in. These parameters are described in detail in Table I-1 and the parameter values used in this report are displayed at the end of the program listing in Section V.

Step 2.

Costs and emissions storage areas are zeroed and data for one plant are read using the standard input routine (Table I-2).

Step 3.

Subroutine SORT is called to sort plant data by process type number and within the process type by process size in decreasing order.

Electric furnaces within a plant are then regrouped, where possible, to allow pairing of furnaces to a single control device. If one size group of electric furnaces has an odd number of furnaces, the next smaller size group is checked to see if the size is within 25 percent of the first group. If so, one furnace is "transferred" to the larger category to minimize costs. This is done for all electric furnace groups within a plant.

Step 4.

Costs are calculated for one piece of equipment of each size and type using function COST, and the result multiplied by the total number of pieces. In the case of electric furnaces, one-half the actual number of furnaces of a particular size is used if the number is even; if odd, half the next lower even number plus 0.7143 (= 1./1.4) is used.

Emissions are calculated using the actual number of furnaces for all furnace types.

Step 5.

Costs, emissions, and plant identification are punched (using subroutine OUTFI) and printed. Control is transferred to Step 2 for subsequent plant data.

TABLE I-1. - LIST OF PARAMETERS FOR THE IRON AND STEEL PROGRAM

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| A1(5) | a parameters for investment cost. | 1 | 5F8.0 |
| A2(5) | a parameters for annualized cost. | 1 | 5F8.0 |
| B1(5) | b parameters for investment cost. | 2 | 5F8.0 |
| B2(5) | b parameters for annual cost. | 2 | 5F8.0 |
| EFACT | Emission factors for each process type, without control of any kind, for particulates. | 3 | 5F8.0 |
| PCT(5) | Percentage control represented by parameters A1, A2, B1, and B2 for particulates. | 3 | 5F8.0 |
| SIZE (17,5)<br>DCONT (17,5) | Tables of process capacity and corresponding required fractional control level for each of the five unit processes, for particulates. | 4-14 | 16F5.0 |
| EFACT(5) | Same as EFACT for fluoride emissions | 15 | 5F5.0 |
| G(5) | Final control efficiencies for fluoride emissions for each process type. | 15 | 5F5.0 |
| PEFF | Predefined emission level for fluorides in 1967. | 15 | 5F5.0 |

TABLE I-2. - INPUT DATA DESCRIPTION FOR THE IRON AND STEEL PROGRAM

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1 and 2 | | |
| ICODE | Card type code. | 2 | I1 |
| SCODE | Source type code (=7). | 4-5 | F2.0 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| | Card 1 | | |
| TOTCAP | Total plant capacity | 11-20 | F10.0 |
| NPROC | Number of unit processes to be found on card(s) 2. | 21-22 | I2 |
| INP(12) | Plant identification. | 31-78 | 12A4 |
| | Card 2 | | |
| IUNIT(2, 40) | Unit process type number (row 1) and number of that type and size within the plant (row 2) for up to 40 unit processes. | row 1:11-12, 31-32, 51-52 | I2 |
| | | row 2:13-15, 33-35, 53-55 | I3 |
| CEFF(40) | Control efficiency (1967) for up to 40 unit processes. | 16-17,36-37,56-57 | F2.0 |
| CAP(40) | Unit process capacity for up to 40 unit processes. | 18-25,38-45,58-65 | F8.0 |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| Main Program | |
| A1(5), B1(5) | Parameters used by function COST (q.v.) for calculating investment cost. See Table I-1. |
| A2(5), B2(5) | Similar to A1 and B1 for annual cost. |
| AQCR | Variable reserved for metropolitan area number. |
| C1(2) | Investment (C1(1)) and annual (C1(2)) costs for a plant. |
| CAP(40) | Capacity of each unit process for a plant. |
| CEFF(40) | Control efficiency for each unit process as specified for 1967. |
| CO1, CO2 | Temporary storage for unit process investment and capital costs. |
| CONTROL | Required control efficiency as determined from unit process size and type, by linear interpolation from DCONT (q.v.) as necessary. |
| COST | Function subprogram which calculates costs using the general cost equation parameters A1 and B1 or A2 and B2 and required control efficiency, 1967 control efficiency, and control efficiency used in determining the parameters a and b. |
| DC1, DC2, DCAP | Temporary storage variables. |
| DCONT(17,5) | Relates unit process capacity and required control efficiency (Table I-2). |
| DEFF | Temporary storage for 1967 efficiency. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| | Main Program |
| EL(2), E2(2) | Accumulates plant emissions of particulates (E1) and fluorides (E2) for 1967 (E1(1) and E2(1)), and after full control (E1(2) and E2(2)). |
| E11,E12,E01,E02 | Temporary storage for emissions. |
| EFACT(5) | Emission factors for each unit process type for particulate emissions with no control assumed. |
| FACT | Temporary storage of number of units of a process type and size. (see IUNIT). |
| FFACT(5) | Emission factors for each unit process type for fluoride emissions with no control assumed. |
| G(5) | Control level assumed for fluoride control for each unit process (decimal fraction). |
| I,J,K | Dummy variables for indexing. |
| IA | Temporary variable for unit process number (see IUNIT). |
| ICODE | Card type code (column 2). |
| INP(12) | Stores plant name and identification. |
| IUNIT(2,40) | Row 1 of IUNIT stores the unit type number for each unit process (1= open hearth, 2= basic oxygen, 3= electric, 4= sintering windbox, 5= sintering discharge.) Row 2 contains number of unit processes of this size and type within the plant. |
| JPROC,N1,N2 | Temporary storage. |
| NPROC | Number of unit processes within the plant. |
| OUTFI | Standard punched output subroutine. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| | Main Program |
| PCT(5) | Contains the control percentage which the a and b parameters represent for each process type. |
| PEFF(5) | Average control levels for fluorides for each process type, 1967. |
| RSAC1, RSAC2 | RSAC code and special part code for the plant. |
| SC1, SC2 | Temporary variables. |
| SCODE | Source code for the plant (must be 7 for iron and steel plants). |
| SIZE(17,5) | Process size capacity table (Table I-2) associated with DCONT (q.v.). |
| SORT | Subroutine which sorts data into by process type code (ascending) and capacity (descending). |
| TEMP | Temporary variable. |
| TOTCAP | Total plant capacity. |
| | Subroutine SORT |
| CAP,CEFF,IUNIT, NPROC | Variable from main program (qq.v.). |
| A1,A2 | Temporary storage. |
| I,J,K,L,M | Dummy variable for indexing. |
| I1,I2 | Temporary storage. |
| LAST(10) | Vector which stores position of last unit process of each process type. |
| | Function COST |
| A | Parameter a for the cost equation. |
| B | Parameter b for the cost equation. |
| C | Control level required for the unit size. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| CORR | Temporary storage. |
| DC | Process capacity in appropriate units. |
| E | Control efficiency currently existing on the unit process. |
| P | Control level represented by the cost parameters A and B. |
| TEMP | Temporary storage. |

## V. LIST OF THE COMPUTER PROGRAM FOR IRON AND STEEL

```
C     PROGRAM ISTEEL
C     THIS PROGRAM COMPUTES CONTROL COSTS FOR IRON AND STEEL PLANTS.
C
      DIMENSION A(5,6), A1(5), A2(5), B1(5), B2(5), PCT(5), INP(12),
     1 IUNIT(2,40), CAP(40), EFACT(5), CEFF(40), DCONT(17,5), SIZE(17,5)
      DIMENSION G(5), FFACT(5), C1(2), E1(2), E2(2), QEFF(5), PEFF(5)
C
C     READ IN TABLES
C
      READ 5000, A1, A2, B1, B2, EFACT, PCT
 5000 FORMAT(10F8.0)
      READ 5006, SIZE, DCONT
 5006 FORMAT(16F5.0)
      READ 5000, FFACT, G, PEFF
C
C     ZERO OUT DATA STORAGE
C
      DO 30 I=1,2
      DO 10 J=1,40
      IUNIT(I,J)=0
   10 CONTINUE
   30 CONTINUE
      DO 40 I=1,40
      CAP(I)=0.
      CEFF(I)=0.
   40 CONTINUE
      DEFF=0.0
      AQCR=0.0
C
C     THE FOLLOWING PROCESSING OF CARD TYPE 1 WILL BE MOVED TO THE MAIN
C     PROGRAM.
C
   50 READ 5005, ICODE, SCODE, RSAC1, RSAC2, TOTCAP, NPROC, INP
 5005 FORMAT(1X,I1   ,1X,F2.0,A4,A1,F10.0,I2,8X,12A4)
      C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      E2(1)=0.
      E2(2)=0.
      IF(ICODE-1 ) 2000,60,1000
   60 IF(SCODE-7.) 1010,70,1010
   70 JPROC=NPROC
      N1=1
      N2=3
   71 READ 5010, ICODE, SCODE, ((IUNIT(I,J),I=1,2),CEFF(J),CAP(J),J=N1,
     1 N2)
 5010 FORMAT(1X,I1   ,1X,F2.0,5X,3(I2,I3,F2.0,F8.0,5X))
      JPROC=JPROC-3
      IF (JPROC) 73,73,72
   72 N1=N1+3
      N2=N2+3
      GO TO 71
   73 IF (ICODE-2) 1030,80,1030
C
C     SORT DATA BY UNIT NUMBER AND DECREASING CAPACITY.
C
   80 CALL SORT(IUNIT,CEFF,CAP,NPROC)
C
C     CALCULATE COSTS.  FIRST STEP IS TO REALLOCATE UNITS TO MAKE NUMBERS
C     EVEN, WHERE POSSIBLE, FOR ELECTRIC FURNACES.
C
      DO 230 I=1,NPROC-1
      IF (IUNIT(1,I)) 230,230,170
  170 IF (IUNIT(1,I)-3) 230,180,230
  180 IF ((IUNIT(2,I)/2)*2-IUNIT(2,I)) 190,230,190
C
C     NUMBER IS ODD.
C
  190 IF (IUNIT(1,I)-IUNIT(1,I+1)) 230,195,230
  195 IF (CEFF(I)-CEFF(I+1)) 230,200,230
  200 IF ((CAP(I)-CAP(I+1))/CAP(I)-.25) 210,210,230
  210 IUNIT(2,I)=IUNIT(2,I)+1
      IUNIT(2,I+1)=IUNIT(2,I+1)-1
      IF (IUNIT(2,I+1)) 230,220,230
  220 DO 225 J=I+1,NPROC-1
      CAP(J)=CAP(J+1)
      DO 225 K=1,2
      IUNIT(K,J)=IUNIT(K,J+1)
  225 CONTINUE
      CAP(NPROC)=0.
      IUNIT(1,NPROC)=0
      IUNIT(2,NPROC)=0
      NPROC=NPROC-1
  230 CONTINUE
C
C     DO ACTUAL COST CALCULATIONS.
C
      DO 290 I=1,NPROC
      CO1=0.0
      CO2=0.0
      EO1=0.0
      EO2=0.0
      E11=0.0
      E12=0.0
      DCAP=CAP(I)
      IA=IUNIT(1,I)
      DEFF=CEFF(I)
      DO 235 J=2,17
      IF (SIZE(J,IA)-DCAP) 235,231,232
  231 CONTRL=DCONT(J,IA)
      GO TO 240
  232 DC1=DCONT(J,IA)
      DC2=DCONT(J-1,IA)
      SC1=SIZE(J,IA)
      SC2=SIZE(J-1,IA)
      CONTRL=DC2+(DC1-DC2)/(SC1-SC2)*(DCAP-SC2)
      GO TO 240
  235 CONTINUE
  240 IF (IA        -3) 241,242,241
  241 FACT=FLOAT(IUNIT(2,I))
      GO TO 270
  242 G(3)=CONTRL*.85
      IF (IUNIT(2,I)-1) 241,241,243
  243 IF ((IUNIT(2,I)/2)*2-IUNIT(2,I)) 250,260,250
  250 FACT=FLOAT(IUNIT(2,I)/2)+1./1.4
      GO TO 270
  260 FACT=FLOAT(IUNIT(2,I)/2)
  270 TEMP=COST(A1(IA),B1(IA),PCT(IA),CONTRL,DCAP,DEFF
 5012 FORMAT(2F10.4)                                         )*FACT
      IF (TEMP) 285,285,280
  280 C01=TEMP
      TEMP=COST(A2(IA),B2(IA),PCT(IA),CONTRL,DCAP,DEFF
      C02=TEMP                                               )*FACT
      DCAP=DCAP*FLOAT(IUNIT(2,I))
      E01=EFACT(IA)*DCAP*EFACT(IA)*(1.0-DEFF/100.)
      E02=EFACT(IA)*DCAP*(1.-CONTRL)
      E11=FFACT(IA)*DCAP*PEFF(IA)
      E12=FFACT(IA)*DCAP*(1.-G(IA))
      GO TO 286
  285 E01=EFACT(IA)*DCAP*FLOAT(IUNIT(2,I))*(1.-DEFF)
      E02=E01
      E11=FFACT(IA)*DCAP*FLOAT(IUNIT(2,I))*(1.-DEFF)
      E12=E11
  286 C1(1)=C1(1)+C01
      C1(2)=C1(2)+C02
      E1(1)=E1(1)+E01
      E1(2)=E1(2)+E02
      E2(1)=E2(1)+E11
      E2(2)=E2(2)+E12
  290 CONTINUE
      PRINT 5558, INP
 5558 FORMAT(13H PLANT TOTAL ,12A4)
      PRINT 5555, RSAC1,RSAC2,(IUNIT(J,I),J=1,2),TOTCAP,C1,E1,E2
 5555 FORMAT(2X,A4,A1,I4,I7,F8.2,3F12.2,3F13.2)
      CALL OUTFI(RSAC1,RSAC2,AQCR,7,INP,C1,2,1,E1,5,E2)
      GO TO 50
C
C     ERROR ROUTINES
C
 1000 PRINT 5025
 5025 FORMAT(41H ERROR FOUND IN CARD CODE.  "1" EXPECTED.)
      GO TO 50
 1010 PRINT 5030, SCODE
 5030 FORMAT(27H INVALID SOURCE CODE FOUND.,F10.0)
      GO TO 50
 1030 PRINT 5040, ICODE
 5040 FORMAT(25H INVALID CARD CODE FOUND., I5)
      GO TO 50
      GO TO 50
C
C     OUTPUT ROUTINE
C
 2000 PRINT 5055
 5055 FORMAT(12H-GOOD FINISH)
      STOP
      END
      SUBROUTINE SORT(IUNIT,CEFF,CAP,NPROC)
C
C     THIS SUBROUTINE SORTS THE DATA READ IN BY THE IRON AND STEEL PROGRAM
C     BY ORDER OF UNIT TYPE NUMBER, AND WITHIN UNIT TYPE NUMBER, BY CAP-
```

```
C     ACITY IN DECREASING ORDER.
C
      DIMENSION IUNIT(2,40), CAP(40), LAST(10),CEFF(40)
      DO 5 I=1,10
      LAST(I)=0
    5 CONTINUE
      DO 20 I=1,NPROC-1
      DO 20 J=I+1,NPROC
      IF (IUNIT(1,I)-3) 20,9,20
    9 IF (IUNIT(1,I)-IUNIT(1,J)) 20,20,10
   10 I1=IUNIT(1,I)
      I2=IUNIT(2,I)
      A1=CAP(I)
      A2=CEFF(I)
      IUNIT(1,I)=IUNIT(1,J)
      IUNIT(2,I)=IUNIT(2,J)
      CAP(I)=CAP(J)
      CEFF(I)=CEFF(J)
      IUNIT(1,J)=I1
      IUNIT(2,J)=I2
      CAP(J)=A1
      CEFF(J)=A2
   20 CONTINUE
      DO 40 I=2,NPROC
      IF (IUNIT(1,I)-IUNIT(1,I-1)) 40,40,30
   30 J=IUNIT(1,I-1)
      LAST(J)=I-1
   40 CONTINUE
      LAST(J+1)=NPROC
      K=LAST(2)+1
      L=LAST(3)
      DO 60 J=K,L-1
      DO 60 M=J+1,L
      IF (CAP(J)-CAP(M)) 50,50,60
   50 A1=CAP(J)
      A2=CEFF(J)
      I1=IUNIT(1,J)
      I2=IUNIT(2,J)
      CAP(J)=CAP(M)
      CEFF(J)=CEFF(M)
      IUNIT(1,J)=IUNIT(1,M)
      IUNIT(2,J)=IUNIT(2,M)
      CAP(M)=A1
      CEFF(M)=A2
      IUNIT(1,M)=I1
      IUNIT(2,M)=I2
   60 CONTINUE
      RETURN
      END
      FUNCTION COST(A,B,P,C,DC,E)
C
C     THIS FUNCTION CALCULATES THE ACTUAL CONTROL COSTS FOR IRON + STEEL
C     FROM THE FUNCTIONAL RELATIONSHIP USED IN THE OU-455 NAPCA PROJECT.
C
      TEMP=A*(DC**B)
      CORR=(ALOG10(1./(1.-C))-ALOG10(1./(1.-E)))/ALOG10(1./(1.-P))
      COST=TEMP*CORR
      RETURN
      END
```

```
DATA IDENTIFIED IN THE LIST OF PARAMETERS.

 14.000  17 888  12.902   3 400  42.559   6.750  12.803   8.400   2.961   9.115
     77      .7       7    .692    .267     .74     .83      .7    .712    .331
    4 8    18.5    17 3     2.4     2.6    .920    .991    .880    .938    .950
   0.  10.  20.  30.  40.  50. 100. 150. 200. 250. 300. 350. 400. 450. 500. 550.
 600.  50. 100. 150. 200. 250. 300. 300.   0.   0.   0.   0.   0.   0.   0.   0.
   0.   0.   0.  10.  20.  25.  50. 100. 150. 200. 250. 250.   0.   0.   0.   0.
   0.   0.   0.1000.2000.3000.4000.5000.6000.6000.   0.   0.   0.   0.   0.   0.
   0.   0.   0.   0.1000.2000.3000.4000.5000.6000.6000.6000.   0.   0.   0.   0.
   0.   0.   0.   0.   0. .830 .850 .867 .879 .888 .895 .914 .923 .940 .949 .956
  961 .964 .967 .971 .973 .975 .980 .990 .993 .994 .995 .996 .996   .0   .0   .0
   .0   .0   .0   .0   .0   .0   .0 .776 .809 .832 .840 .870 .890 .920 .940 .950
  950   .0   .0   .0   .0   .0   .0   .0 .950 .970 .980 .983 .986 .988 .988   .0
    0   .0   .0   .0   .0   .0   .0   .0   .0 .950 .970 .980 .985 .987 .989 .989
    0   .0   .0   .0   .0   .0   .0   .0   .0   .0
    .15       .92      1.38        0.        0.       .99       .99       .85        0.        0.
   .878      .475      .451      .000      .000
```

# APPENDIX J

## Computer Program for Kraft (Sulfate) Pulp

# Appendix J

# Computer Program for Kraft (Sulfate) Pulp

## I. INTRODUCTION

The kraft pulp industry contributes to air pollution by emitting significant amounts of particulates. The recovery furnaces also emit sulfur oxides but not in amounts that exceed the assumed regulation standard.

The purpose of this appendix is to describe a computer program designed to compute the emissions before and after added controls and the investment and annual operating costs for controlling these emissions. The data base for this program is not ideal insofar as it contains only the name, location, and daily capacity of each plant. A general flow diagram of the program logic is shown in Figure J-1.

Section II of this report gives the major assumptions in the computer program. Section III explains the program logic and gives tables of input data with formats to enable one to use the program. Section IV is a glossary of FORTRAN names for the kraft (sulfate) pulp computer program, and Section V is a listing of the computer program.

## II. MAJOR ASSUMPTIONS

Some major assumptions had to be made in regard to the plant configuration due to the absence of sufficient plant data. A model plant configuration is computed in Subroutine CONFIG for each plant based on the daily plant capacity and average capacities for each process type. The average capacities for each process type, AVGC(I), are input data in order to facilitate changes. When detailed information on the equipment in the pulp plants are available, Subroutine CONFIG can be discarded along with the input data on average capacities for each process type. NUMB(I) and SIZE(I) will then become input data for each process type I for all plants.

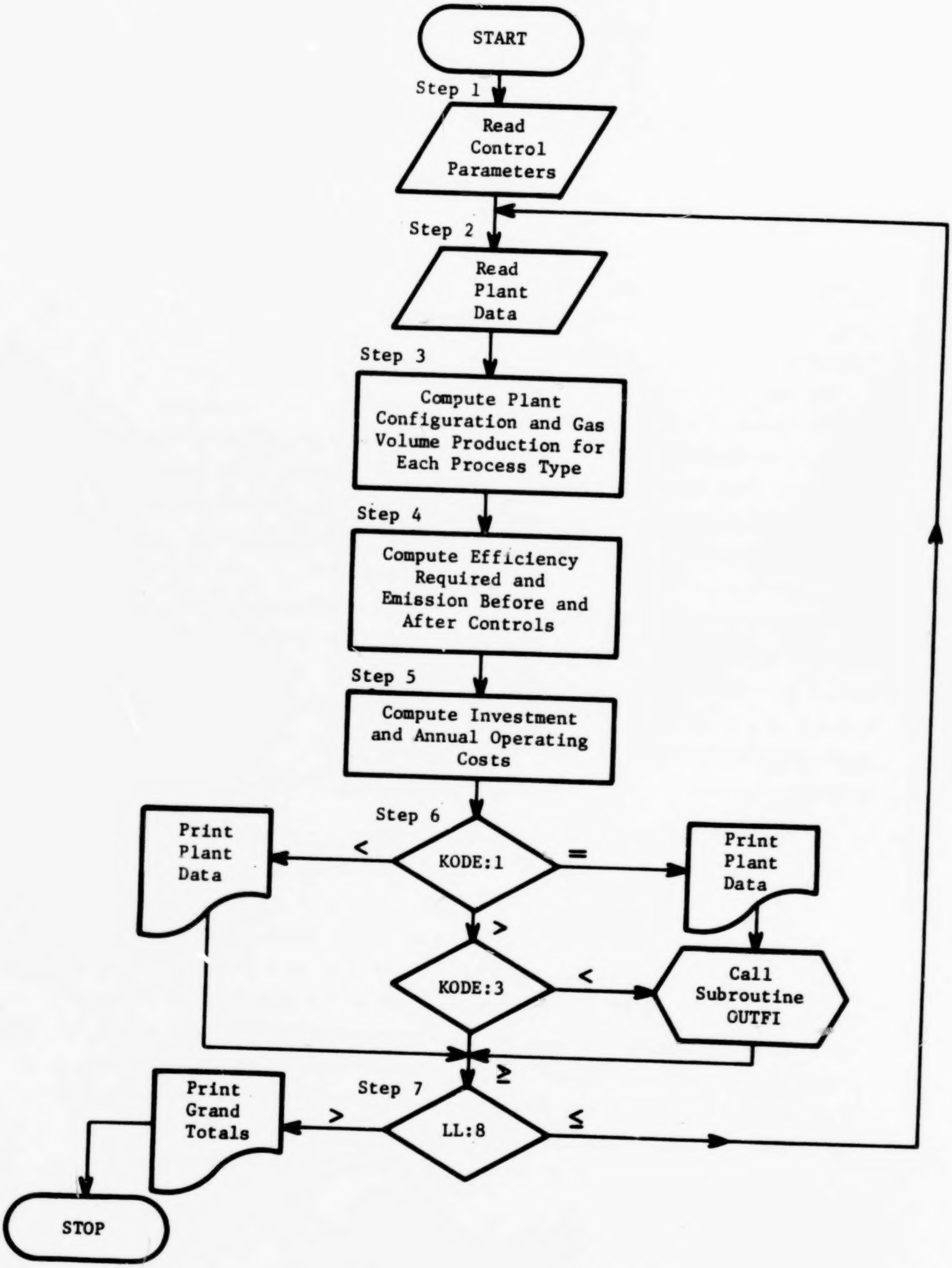

START
Step 1
Read Control Parameters
Step 2
Read Plant Data
Step 3
Compute Plant Configuration and Gas Volume Production for Each Process Type
Step 4
Compute Efficiency Required and Emission Before and After Controls
Step 5
Compute Investment and Annual Operating Costs
Step 6
KODE:1
<
Print Plant Data
=
Print Plant Data
>
KODE:3
<
Call Subroutine OUTFI
≥
Step 7
LL:8
>
Print Grand Totals
≤
STOP

Fig. J-1. Flow Chart of Program PULP.

Other major assumptions are as follows:

a) All recovery furnaces are assumed to be of equal size within a plant and to have an associated smelt-dissolving tank of corresponding capacity. The type of control varies with the type of process equipment used; i.e., recovery furnaces and smelt-dissolving tanks are assigned venturi scrubbers that use a weak black liquor scrubbing medium; lime kilns are assigned venturi scrubbers; and bark boilers are assigned specially-designed multitube collectors. Input data for EQUIP(I) determine the type of equipment for each process I.

b) Installation costs are three times the equipment cost for the black liquor scrubbers, two times for the wet scrubbers, and two times for the multicycloner.

c) Annual costs are operating costs plus 20 percent of the investment.

## III. PROGRAM OPERATIONS

Step 1.

The first step in the program is to read in certain control parameters such as type of equipment to be used for each process type, emission factors, etc., as shown in Table J-1. These data are generally constant, but are input as variables so that the values may be altered with ease when and if more accurate data become available. Table J-1 lists the data in the same order in which it is read into the program. The actual values are shown at the end of the program listing.

Step 2.

After this initial input of data, the program goes into a loop which computes the amounts of emissions and costs for controlling the emissions for each plant. The first step in the loop is to read in the plant data as shown in Table J-2.

Step 3.

Subroutine CONFIG is called in order to determine the plant configuration which is based on total plant capacity and the average capacities of each process type, AVGC(I), for all plants. This subroutine returns the number, NUMB(I), and size, SIZE(I), for each of the four processes.

The gas volume production, GVPPT(I), for each process type I is then computed as follows:

$$GVPPT(I) = GASVOL(I) / NUMB(I) / 1000., \text{ where}$$
$$GASVOL(I) = (TOTCAP/100)\ GVP(I).$$

Step 4.

The values for GVPPI(I) are then used in order to do a table lookup of the required efficiency, RE(I), for each process type I. Table J-3, "Required Removal Efficiencies in Kraft Processes," shows the required efficiency versus gas volume as used in the table lookup routine. Three values along witn other control parameters are again at the end of the program listing. The emissions in tons are then computed at the required efficiency level.

Step 5.

Subroutine COSTEQ is called in order to return the cost of equipment for each process type as a function of inlet gas volume (1000 acfm) and the number required of each type. The first three process types are designated as equipment type, EQUIP(I), with input data as follows:

1 for 316 ELC Stainless Steel,
2 for 304 venturi/MS CLS, and
3 for all mild steel.

EQUIP (4) is always for multitube collectors. Subroutine COSTOP returns the annual operating cost, AOCOST(I), for the selected control system for each process type, using analytical functions to represent the appropriate curve. The investment and annual costs for each process type is then computed. Installed costs are three times the equipment costs for process 1, and 2 times the equipment cost for processes 2, 3, and 4. Annual costs are operating costs plus 20 percent of the investment cost. The emissions and costs for all processes are then summed and these values are also added to a grand total.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

Step 7.

When the program reaches a data card with an "8" or a "9" punched in CNO (Column 2), the grand totals for emissions and costs are printed out. If the value for CNO is "8," the totals are zeroed out and the summing process is resumed with subsequent regions until another "8" or "9" appears in the "CNO" column. If the value for CNO is "9," the program is terminated after printing the total costs and emissions.

TABLE J-1. - CONTROL PARAMETERS FOR PROGRAM PULP

| FORTRAN Name | Definition* | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Code to denote when to bypass Subroutine OUTFI and when to print plant data. | 1-5 | I5 |
| | Card 2 | | |
| EQUIP(I) | Type of equipment required for each process type I. | 1-40 | 4F10.3 |
| | Card 3 | | |
| COEFF(I) | Present control efficiencies (percent) for each process type I. | 1-40 | 4F10.3 |
| | Card 4 | | |
| ER(I) | Uncontrolled emission rates (lbs/ ton of air dried pulp) for each process type I. | 1-40 | 4F10.3 |
| | Card 5 | | |
| ERAC(I) | Present controlled emission rates (lbs/ ton of air dried pulp) for each process type I. | 1-40 | 4F10.3 |
| | Card 6 | | |
| GVOL(I,J) | Arbitrary values for gas volume ($10^3$ acfm) for each process type I. | 1-72 | 12F6.2 |
| | Card 7 | | |
| REQR(I,J) | Percent efficiency required for each process type I as a function of the gas volume, GVOL(I,J), in No. 5. | 1-72 | 12F6.2 |
| | Card 8 | | |
| GVP(I) | Gas volume production (acfm/100 tons/ day) for each process type I. | 1-40 | 4F10.0 |
| | Card 9 | | |
| AVGC | Average capacity (tons/day) for each process type I. | 1-40 | F10.2 |
| OPCT | Percent of total capacity plant is operating. | 41-50 | F10.2 |

* Process types are as follows:

I = 1, Recovery furnaces
I = 2, Lime kilns
I = 3, Smelt-dissolving tanks
I = 4, Bark boilers

### TABLE J-2. - PLANT DATA FOR PROGRAM PULP

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| CNO | Card numbers (1). | 1-2 | I-2 |
| SCODE | Source code (6). | 3-5 | I-3 |
| RSAC | National location code. | 6-9 | A4 |
|  | Blank. | 10 |  |
| TOTCAP | Plant capacity, tons/day. | 11-20 | F10.0 |
| INP(J) | Plant description such as name and location. | 21-68 | 12A4 |

TABLE J-3. - REQUIRED REMOVAL EFFICIENCIES FOR KRAFT PROCESSES

| Gas Volume (1000 acfm) | Percent Efficiency Required |
|---|---|
| Recovery furnaces | |
| 25 | 95.0 |
| 75 | 97.8 |
| 125 | 98.5 |
| 175 | 98.9 |
| 225 | 99.1 |
| 275 | 99.3 |
| 325 | 99.4 |
| Lime kilns | |
| 5 | 96.9 |
| 15 | 97.8 |
| 25 | 98.2 |
| 35 | 98.3 |
| 45 | 98.6 |
| 55 | 98.8 |
| 65 | 98.9 |
| 75 | 99.0 |
| 85 | 99.1 |
| 95 | 99.2 |
| 105 | 99.3 |
| Smelt-dissolving tanks | |
| 2.5 | 84.0 |
| 7.5 | 93.2 |
| 12.5 | 95.2 |
| 17.5 | 96.0 |
| 22.5 | 96.4 |
| 55.0 | 98.8 |
| Bark boilers | |
| 16 | 93 |
| 24 | 93 |
| 32 | 93 |
| 40 | 95 |
| 48 | 95 |
| 56 | 95 |
| 64 | 96 |
| 72 | 96 |
| 80 | 97 |

# IV. GLOSSARY OF FORTRAN NAMES USED IN COMPUTER PROGRAM FOR KRAFT (SULFATE) PULP

| FORTRAN Name | Definition |
|---|---|
| AFTER(4) | Emissions at required level of efficiency for each process type I. |
| AOCOST(4) | Annual operating costs for each process type I. |
| AVGC(4) | Average capacities of each process type I. |
| BEFORE(4) | Emissions in tons before any controls are installed for process type I. |
| CNO | Card number for plant data except to terminate program at which time it is 9. |
| CO(2) | Investment and annual operating costs for each plant. |
| COEFF(4) | Input variable giving the present particulate control efficiency (percent) for each process type I. |
| CONFIG | Subroutine to compute plant configuration. |
| COST(2) | Sum of investment and annual costs. |
| COSTEQ | Subroutine to compute equipment costs. |
| COSTI(4) | Investment costs for each process type I. |
| COSTOP | Subroutine to compute operating costs. |
| COSTYR(4) | Annual costs for each process type I. |
| EMS(2) | Sum of particulate emissions both before and after added controls. |
| EM1(2) | Sum of 1967 and controlled emissions for each plant. |
| EQCOST(4) | Equipment costs for each process type I. |
| EQUIP(4) | Input data to determine type of equipment to use for each process type I. |
| ER(4) | Uncontrolled emission rates (lbs/ton of air dried pulp) for particulates for each process type I. |

# Glossary of FORTRAN Names Used in Computer Program for Kraft (Sulfate) Pulp (continued)

| FORTRAN Name | Definition |
|---|---|
| ERAC(4) | Controlled emission rates (lbs/ton of air dried pulp) for particulates for each process type I. |
| GASVOL | Total gas volume production (acfm/100 tons/day) for plant. |
| GVOL(4,12) | Arbitrary values of gas volume (1000 acfm) in table of gas volume vs. required efficiency for the I-th process. |
| GVP(4) | Gas volume production (acfm/100 tons/day for each process type I. |
| KODE | Code to determine when to bypass OUTFI and/or printout plant data. |
| GVPPT(4) | Gas volume production ($10^3$ acfm) per process type I. |
| IAQCR | Dummy parameter required in Subroutine OUTFI. |
| ICODE | Dummy parameter required in Subroutine OUTFI. |
| INP(12) | Name and location of plant. |
| JNE | Numerical value assigned as emission number (1-6) of emissions 1 to 4 for use in Subroutine OUTFI. |
| LIM | Number of values (j) in Table of REQR(I,J). |
| NE | Total number of pollutants from source. |
| NOP | Number of plant in sequential order. |
| NS | Numerical value assigned to source. |
| NUMB(4) | Numbers of control equipment required for each process type I. |
| OPCT | Ratio of plant's operation to total capacity of plant (equals 1.0 when operating at full capacity). |
| PRES(4) | 1967 emission totals for each process type I. |
| RATIO | Ratio of difference between actual gas volume of process type and the input table value. |

## Glossary of FORTRAN Names Used in Computer Program for Kraft (Sulfate) Pulp (continued)

| FORTRAN Name | Definition |
|---|---|
| RE | Required efficiency vs. gas volume from table lookup. |
| REQR(4, 12) | Efficiency required (percent) for each of the four processes as a function of gas volume, GVOL(I,J). |
| RSAC | National location code. |
| SCODE | Source code number. |
| SIZE(4) | Size of each process I. |
| SUM(7) | Sum of emissions and costs for all processes. |
| TOTCAP | Plant capacity in tons/day. |

## V. LISTING OF THE COMPUTER PROGRAM FOR KRAFT (SULFATE) PULP

```
      PROGRAM PULP
      REAL NUMB
      INTEGER CNO,SCODE,RSAC
      DIMENSION INP(20),EQUIP(4),COEFF(4),GVP(4),GASVOL(4),NUMB(4),
     2GVOL(4,12),       EQCOST(4),COSTI(4),COSTYR(4),RE(4),ER(4),PART(4),
     3GVPPT(4),AOCOST(4),TYPE(4),SIZE(4), AVGC(4),REQR(4,15),
     4BEFORE(4),AFTER(4) ,SUM(10),ERAC(4),PRES(4)
      DIMENSION COST(2),EM1(2) ,EMS(2),CO(2)
      COMMON GVPPT,EQUIP,EQCOST,NUMB,AOCOST,TOTCAP,AVGC,SIZE,OPCT
      DO 2 I = 1,2
      COST(I) = 0.
    2 EM1(I) = 0
      NS = 6
      NE = 1
      JNE = 1
      ICODE = 0
      IAQCR = 0
      NOP = 0
C     READ IN CONTROL CARDS
C        ER(I) IS THE UNCONTROLLED PARTICULATE EMISSION RATE (LB/TON
C          AIR DRIED PULP) FOR PROCESS TYPE I.
C        ERAC(I) IS THE PRESENT CONTROLLED ESTIMATED PARTICULATE
C          EMISSION RATE (LB/TON AIR DRIED PULP) FOR PROCESS TYPE I.
      READ 460, KODE
  460 FORMAT (I2)
      READ 500, (EQUIP(I),I=1,4)
      READ 500, (COEFF(I), I = 1,4)
      READ 500, (ER(I), I = 1,4)
      READ 500, (ERAC(I), I = 1,4)
      DO 10 I = 1,4
      READ 502,(GVOL(I,J), J = 1,12)
      READ 502,(REQR(I,J), J = 1,12 )
   10 CONTINUE
C     READ IN GAS VOL.(ACFM/100 T/D) VS PROCESS(I) WHERE
C          I=1 FOR RECOVERY FURNACE,
C          I=2 FOR LIME KILN,
C          I=3 FOR SMELT-DISSOLVING TANK, AND
C          I=4 FOR BARK BOILER.
C     DETERMINE CAPACITIES OF RECOVERY FURNACES,SMELT-DISSOLVING TANKS,
C          AND BARK-BURNING BOILERS
      READ 520, (GVP(I),I=1,4)
      READ 540,(AVGC(I),I=1,4),OPCT
      PRINT 398
  398 FORMAT (115H                    KRAFT PULP POLLUTANTS (TONS/YEAR) - AIR P
     2OLLUTION CONTROL COSTS ($1000)                                           ,//)
      PRINT 598
      PRINT 600
   15 CONTINUE
C     READ IN PLANT DATA
      READ 510, CNO,SCODE,RSAC,TOTCAP,(INP(I),I=1,12)
  510 FORMAT (I2,I3,A4,X,F10 0,10X,12A4)
      IF(CNO-8)15,800,810
   16 CONTINUE
```

```
      NOP =NOP + 1
      CALL CONFIG
C    COMPUTE THE GAS VOL. PRODUCTION (1000 ACFM) FOR EACH PROCESS TYPE
C      IN ORDER TO DO A TABLE LOOKUP OF REQUIRED EFFICIENCY.
C         GVPPT(I) IS THE GAS VOLUME (1000) PER PROCESS TYPE I.
      DO 20 I=1,4
      GASVOL(I) =(TOTCAP*GVP(I))/100.
 20   GVPPT(I)=(GASVOL(I)/NUMB(I))/1000.
C
C          THE FOLLOWING LOOP DOES THE TABLE LOOKUP OF REQUIRED EFFICIENCY
C            (RE(I)) FOR EACH PROCESS TYPE I.
      DO 150 I=1,4
      IF(I-1)40,40,50
 40   LIM = 6
      GO TO 100
 50   IF(I-3)60,70,80
 60   LIM =12
      GO TO 100
 70   LIM = 7
      GO TO 100
 80   LIM =10
      GO TO 100
 100  CONTINUE
      DO 130 J =1,LIM
      IF(GVOL(I,J)-GVPPT(I))130,120,110
 110  RATIO = (GVOL(I,J) - GVPPT(I))/(GVOL(I,J) - GVOL(I,J-1))
      RE(I) = RATIO * (REQR(I,J) - REQR(I,J-1)) + REQR(I,J-1)
      GO TO 131
 120  RE(I) = REQR(I,J)
      GO TO 131
 130  CONTINUE
 131  CONTINUE
      RE(I) = RE(I)/100.
      IF(GVPPT(I)- GVOL(I,LIM))150,140,140
 140  RE(I) =REQR(I,LIM)/100
 150  CONTINUE
C     THE FOLLOWING COMPUTES THE PARTICULATE EMISSION RATE BEFORE AND
C       AFTER ADDED CONTROLS - (LB/TON AIR DRY PULP)
      DO 152 I =1,4
      BEFORE(I) = (TOTCAP * 365.0 * ER(I)    )/2000.0
      PRES(I)  =  (TOTCAP * 365.0 * ERAC(I) )/2000.0
 152  AFTER(I) = (1.0 - RE(I)) * BEFORE(I)
      CALL COSTEQ
      CALL COSTOP
C COMPUTE THE INVESTMENT COST, COSTI(I)
      COSTI(1)= 3.0 * EQCOST(1)
      DO 160 I = 2,4,1
      COSTI(I)=2.0 * EQCOST(I)
 160  COSTYR(I) = 0.2* COSTI(I) + AOCOST(I)
      COSTYR(1) = 0.2* COSTI(1) + AOCOST(1)
      DO 175 J = 1,7
 175  SUM(J) = 0.
      DO 180 I = 1,4
      SUM(1) = SUM(1) + PRES(I)
      SUM(2) = SUM(2) + AFTER(I)
      SUM(3) = SUM(3) + EQCOST(I)
      SUM(4) = SUM(4) + AOCOST(I)
      SUM(5) = SUM(5) + COSTI(I)
      SUM(6) = SUM(6) + COSTYR(I)
 180  CONTINUE
      DO 190 I = 1,2
      COST(I) = COST(I) + SUM(I+4)
 190  EM1(I) = EM1(I) + SUM(I)
      EMS(1) = SUM(1) + EMS(1)
      EMS(2) = SUM(2) + EMS(2)
      CO(1) = SUM(5) + CO(1)
      CO(2) = SUM(6) + CO(2)
      IF(KODE-1)189,191,188
 188  IF(KODE-3)192,15,15
 189  CONTINUE
      PRINT 610,NOP, (INP(I),I=1,12),TOTCAP,SUM(1),SUM(2),SUM(5),SUM(6),
     2RSAC
      GO TO 15
 191  CONTINUE
      PRINT 610,NOP, (INP(I),I=1,12),TOTCAP,SUM(1),SUM(2),SUM(5),SUM(6),
     2RSAC
 192  CONTINUE
      CALL OUTFI (RSAC,ICODE,IAQCR,NS,INP,CO   ,NE,JNE,EMS)
      GO TO 15
 500  FORMAT (4F10.3)
 502  FORMAT (12F6.2)
 520  FORMAT (4F10.0)
 540  FORMAT (5F10.2)
 598  FORMAT (115H
     2          PRESENT  CONTROLLED INVESTMENT     ANNUAL                )
 600  FORMAT (115H NO. PLANT NAME                           LOCATION            TONS/
     2DAY     EMISSIONS EMISSIONS COSTS($1000) COSTS($1000)    RSAC    ,//)
 610  FORMAT (I5,2X,12A4,F10.0,2F10.2,2F12.3,6X,A4)
 800  CONTINUE
      PRINT 900, EM1(1),EM1(2),COST(1),COST(2)
 900  FORMAT (1H0,58X,4F12.0)
      DO 802 I = 1,2
      EM1(I) = 0.
 802  COST(I) = 0.
      GO TO 15
 810  CONTINUE
      PRINT 900, EM1(1),EM1(2),COST(1),COST(2)
      PRINT 910, EMS(1),EMS(2),CO(1),CO(2)
 910  FORMAT (//,12H TOTALS ARE ,47X,4F12.0)
      STOP
      END

      SUBROUTINE COSTEQ
C        THE PURPOSE OF THIS SUBROUTINE IS TO CONMPUTE COSTS OF
C        EQUIPMENT ($1000), EQCOST(I), AS A FUNCTION OF INLET
C        GAS VOLUME (1000 ACFM)), GVPPT(I), AND NUMBER OF EACH
C        EQUIPMENT REQUIRED, NUMB(I), FOR EACH PROCESS TYPE I.
C        THE FIRST THREE PROCESS TYPES ARE DESIGNATED AN EQUIPMENT TYPE,
C        EQUIP(I), AS FOLLOWS
C              1 FOR 316 ELC STAINLESS STEEL
C              2 FOR 304 VENTURI/MS CLS
C              3 FOR ALL MILD STEEL
C        EQCOST(4) IS ALWAYS RETURNED AND IS FOR COST OF MULTI-TUBE COLL.
      REAL NUMB
      DIMENSION GVPPT(4),EQUIP(4),EQCOST(4),NUMB(4),AOCOST(4),AVGC(4),
     2SIZE(4)
      COMMON GVPPT,EQUIP,EQCOST,NUMB,AOCOST,TOTCAP,AVGC,SIZE,OPCT
      DO 150 I=1,3
      IF(GVPPT(I)-60.000)10,10,100
10    IF(GVPPT(I)-4.000)12,12,50
12    EXP = 0.3125
      IF(EQUIP(I)-2.0)20,30,40
20    A = 3.5
      GO TO 150
30    A = 2.9
      GO TO 150
40    A = 2.2
      GO TO 150
50    IF(EQUIP(I) -2.0)60,70,80
60    A = 2.4
62    EXP = 0.59375
      GO TO 150
70    A = 2.0
      GO TO 62
80    A = 1.6
      EXP = 0.53125
      GO TO 150
100   EXP = 0.812
      IF(EQUIP(I)-2.0)110,120,130
110   A = 3.5
      GO TO 150
120   A = 2.9
      GO TO 150
130   A = 2.2
      GO TO 150
150   EQCOST(I) =(A*GVPPT(I)** EXP)*NUMB(I)
      EQCOST(4) =(0.22 * GVPPT(4) ) * NUMB(4)
      RETURN
      END

      SUBROUTINE COSTOP
C     THIS SUBROUTINE COMPUTES THE ANNUAL OPERATION COSTS FOR THE SELECTED
C        CONTROL SYSTEM I
C            I      PRESSURE DROP         CONTROL SYSTEM
C            -      -------------         --------------
C            1      30-INCH W.G.          VENTURI SCRUBBER
C            2      20-INCH W.G.          VENTURI SCRUBBER
C            3      10-INCH W.G.          VENTURI SCRUBBER
C            4      4-5 INCH W.G.         MULTI-CYCLONE
      REAL NUMB
      DIMENSION GVPPT(4),EQUIP(4),EQCOST(4),NUMB(4),AOCOST(4),AVGC(4),
     2SIZE(4)
      COMMON GVPPT,EQUIP,EQCOST,NUMB,AOCOST,TOTCAP,AVGC,SIZE,OPCT
C
      AOCOST(1) =(.647* GVPPT(1)** 0.9743 + 1.0) * NUMB(1)
      AOCOST(2) =(.482 * GVPPT(2)** 0.97   + 1.0 ) * NUMB(2)
      AOCOST(3) =(.270 * GVPPT(3)** 0.983  + 1.0 ) * NUMB(3)
      AOCOST(4) =(.1040* GVPPT(4) + 0.20  ) * NUMB(4)
      RETURN
      END

      SUBROUTINE  CONFIG
      REAL NUMB
      DIMENSION GVPPT(4),EQUIP(4),EQCOST(4),NUMB(4),AOCOST(4),AVGC(4),
     2SIZE(4)
      COMMON GVPPT,EQUIP,EQCOST,NUMB,AOCOST,TOTCAP,AVGC,SIZE,OPCT
C     THIS SUBROUTINE DETERMINES THE PLANT CONFIGURATION BASED ON TOTAL
```

```
C     CAPACITY.
C      NUMB(I) IS THE NUMBER OF EQUIPMENT PROCESSES OF EACH TYPE WHERE
C       TYPE= 1 FOR RECOVERY FURNACES,
C       TYPE = 2 FOR LIME KILNS,
C       TYPE =3 FOR SMELT-DISSOLVING TANKS, AND
C       TYPE =4 FOR BARK BOILERS
C       SIZE(I) = SIZE OF PROCESS TYPE
      DO 60 I =1,4
      IF(TOTCAP-2.0*AVGC(I))10,10,20
 10   NUMB(I) = 1
      GO TO 50
 20   IF (TOTCAP - 4.0*AVGC(I))30,30,40
 30   NUMB(I) = 2
      GO TO 50
 40   IF(TOTCAP - 6.0*AVGC(I))44,44,42
 42   CONTINUE
      ITEMP = (TOTCAP/AVGC(I)) + 1.0
      NUMB(I) = ITEMP
      GO TO 50
 44   NUMB(I) = 3
 50   SIZE(I) = (TOTCAP/NUMB(I)) * OPCT
 60   CONTINUE
      RETURN
      END
```

```
 INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS:


0
       2 0        2.0        2 0        4.0
    0 860      0.800      0.500      0.750
     150.         94.        20.        18.
   21 000     18.700     10.000      4.500
     0  2500   7500 12500 17500 22500 27500 32500
  9500  9500   9750  9850  9890  9910  9930  9940
     0   500   1500  2500  3500  4500  5500  6500  7500  8500  9500 10500
  9690  9690   9780  9820  9830  9860  9880  9890  9900  9910  9920  9930
     0   250    750  1250  1750  2250  5500
  8400  8400   9320  9520  9600  9640  9880
     0  1600   2400  3200  4000  4800  5600  6400  7200  8000
  9300  9300   9300  9300  9500  9500  9500  9600  9600  9700
   25000.      3200.      3100.      8000.
   266.00     265.00     410.00     360 00      1.00
```

# APPENDIX K

## Computer Program for Lime

## Appendix K

## Computer Program for Lime

### I. INTRODUCTION

The lime industry as considered in this program includes those plants which produce lime by a kiln process from limestone for commercial sale. Lime regeneration kilns are not included.

The lime industry uses two types of kilns--rotary and vertical. Data for the lime industry consisted only of plant location. However, for computer program flexibility, the Lime program includes a processing capability when all three types of input data are known: (1) plant location (model plant technique); (2) total capacity; and (3) details concerning unit process.

The remainder of this appendix is organized as follows: Section II lists the assumptions on which this program is based; Section III describes the actual program operations; Section IV is a glossary of the FORTRAN names used in the program; and Section V contains a listing of the program. Figure K-1 is a flow chart for the Lime program.

### II. ASSUMPTIONS

The assumptions on which the program operations are based are:

a) Particulates are the emission type to be controlled.

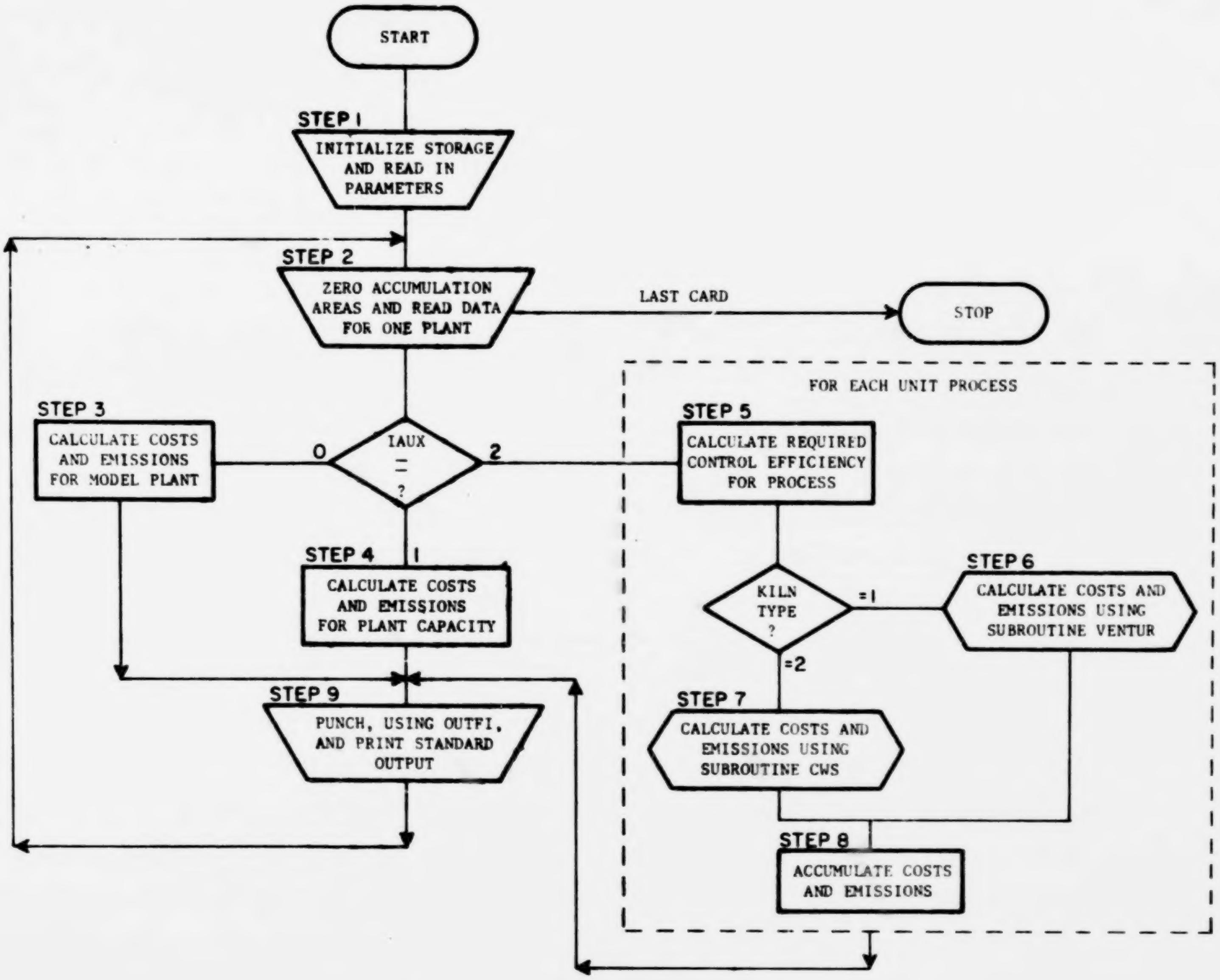
b) The process weight rate standard applies.

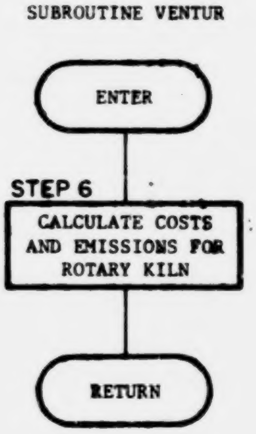
c) There are two kiln types, vertical and rotary.

d) A minimum of 80 percent removal efficiency is required for process control and material recovery, and is, therefore, not charged to air pollution control costs.

e) Table lookup with linear interpolation is a sufficiently accurate method of calculating costs.

The parameters used for the calculations made in this report are listed in Section V and described in Table K-1.


START
STEP 1
INITIALIZE STORAGE AND READ IN PARAMETERS
STEP 2
ZERO ACCUMULATION AREAS AND READ DATA FOR ONE PLANT
LAST CARD
STOP
FOR EACH UNIT PROCESS
STEP 3
CALCULATE COSTS AND EMISSIONS FOR MODEL PLANT
0
IAUX = ?
2
STEP 5
CALCULATE REQUIRED CONTROL EFFICIENCY FOR PROCESS
STEP 4
1
CALCULATE COSTS AND EMISSIONS FOR PLANT CAPACITY
KILN TYPE ?
=1
STEP 6
CALCULATE COSTS AND EMISSIONS USING SUBROUTINE VENTUR
=2
STEP 9
PUNCH, USING OUTFI, AND PRINT STANDARD OUTPUT
STEP 7
CALCULATE COSTS AND EMISSIONS USING SUBROUTINE CWS
STEP 8
ACCUMULATE COSTS AND EMISSIONS


SUBROUTINE VENTUR
ENTER
STEP 6
CALCULATE COSTS AND EMISSIONS FOR ROTARY KILN
RETURN

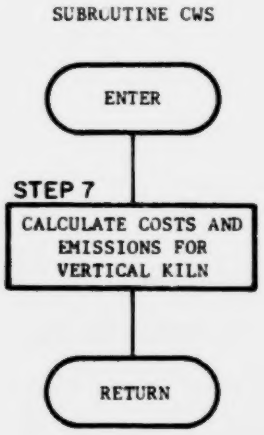

SUBROUTINE CWS
ENTER
STEP 7
CALCULATE COSTS AND EMISSIONS FOR VERTICAL KILN
RETURN

Fig. K-1. - Flow Chart for Computer Program Lime.

TABLE K-1. LIST OF PARAMETERS

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| A1(3,20) | Table of capacities (row 1) and corresponding investment costs (row 2) and annualized costs (row 3) for rotary kiln control, Cards 7-12. | 1-80 | 10F8.0 |
| A2(3,20) | Similar to A1 for vertical kiln control. | 1-80 | 10F8.0 |

## III. PROGRAM OPERATIONS

The step numbers listed refer to the flow chart in Figure K-1.

Step 1.

Program storage is initialized and parameters are read in (for list of parameters see Table K-1).

Step 2.

Plant costs and emissions accumulation storage is set to zero. Data for one plant are read in (for list of plant input data see Table K-2). Step 3 is executed next if plant location data only is found (IAUX=0). Step 4 is executed next if total plant capacity is known (IAUX=1). Steps 5 thru 8 are executed if detailed plant data are known (IAUX=2).

Step 3.

Plant costs and emissions are stored as model plant values. Control is transferred to Step 9.

Step 4.

Plant costs and emissions are calculated as proportional to total plant capacity. Control is transferred to Step 9. Steps 5 thru 8 are executed for each unit process within the plant.

Step 5.

Required control efficiency is calculated for the unit process using the process weight rate standard.

## TABLE K-2. - LIST OF PLANT INPUT DATA

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card Type 1 | | |
| | Blank | 1 | 1X |
| ICODE | Card type identification | 2 | I1 |
| IAUX | Input type identification (0 for no capacity, 1 for total capacity only, 2 for detailed data) | 3 | I1 |
| SCODE | Industry code (15 for lime) | 4-5 | F2.0 |
| RSHC1 | RSAC code | 6-9 | A4 |
| RSAC2 | RSAC part code | 10 | A1 |
| TOTCAP | Total plant capacity | 11-20 | F10-0 |
| NPROC | Number of unit processes in detailed plant data (IAUX=2 only) | 21-22 | I2 |
| | Blank | 23 | 1X |
| IR | Reserved for AQCR number | 24-26 | A3 |
| | Blanks | 27-30 | 4X |
| INPUT(12) | Plant name and location | 31-78 | 12A4 |
| | Card Type 2 | | |
| | Same as card type 1 | 1-10 | |
| IUNIT(2,10) | Unit process data for up to 10 10 unit processes. Row 1 contains process type (1 for rotary kiln, 2 for vertical kiln); row 2 contains number of unit processes. | 11-12+13-15,<br>31-32+33-35,<br>51-52+53-55 | I2, I3 |
| EFF(10) | 1967 control efficiency for up to 10 unit processes. | 16-17, 36-37, 56-57 | F2.0 |
| CAP(10) | Capacity for up to 10 unit processes | 18-25, 38-45, 58-65 | F8.0 |
| | BLANKS | 26-30, 46-50, 66-70 | 5X |

Step 6.

If the unit process is a rotary kiln (type 1), Subroutine VENTUR is used to calculate investment and annualized costs using a table lookup procedure. Emissions are calculated. Control is transferred to Step 8.

Step 7.

If the unit process is a vertical kiln (type 2) Subroutine CWS calculates investment and annualized costs using a table lookup procedure. Emissions are calculated.

Step 8.

Costs and emissions are accumulated for the plant.

Step 9.

Standard output is punched by Subroutine OUTFI and printed. Control is transferred to Step 2 for input of data for the next plant. When the last card is read, the program stops.

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| | **Main Program** |
| A1(3,20) | Table of parameters for rotary kiln control costs (see Table K-1). |
| A2(3,20) | Table of parameters for vertical kiln control costs (see Table K-1). |
| AANN | Subroutine call parameter for return of annualized costs. |
| AINV | Subroutine call parameter for return of investment costs. |
| C1(2) | Vector for accumulation of plant costs. |
| CAP(10) | Input storage for unit process capacities (see Table K-2). |
| CWS | Subroutine for calculation of control costs for vertical kilns. |
| E | Temporary storage of process emissions. |
| E1(2) | Vector for accumulation of plant particulate emissions. |
| EFF(10) | Input storage for unit process 1967 control efficiency. |
| FACT | Temporary storage for number of unit processes. |
| I | Indexing parameter. |
| IAUX | Input type code (see Table K-2). |
| ICODE | Card type identification. |
| INPUT(12) | Input storage for plant name and location. |
| IR | AQCR number (see Table K-2). |
| IUNIT(2,10) | Input storage (see Table K-2). |
| NPROC | Number of unit processes to be read. |
| REFF(10) | Storage for calculated required control efficiency for each unit process. |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |
| SCODE | Industry code (15 for lime). |
| TOTCAP | Total plant capacity. |
| VENTUR | Subroutine for calculation of control costs for rotary kiln. |

## Glossary of FORTRAN Names (Continued)

### Subroutines CWS and VENTUR

| FORTRAN Name | Definition |
|---|---|
| A | Parameter for return of investment cost. |
| A1(3,20) | Table of costs for table lookup. |
| B | Parameter for return of annualized cost. |
| C | Unit process capacity. |
| D | Interpolation fraction. |

## V. LISTING OF THE COMPUTER PROGRAM FOR LIME

```
C     PROGRAM LIME
C     THIS PROGRAM CALCULATES CONTROL COSTS AND EMISSIONS FOR LIME.
C
C     TWO KILN TYPES0 ROTARY (1) AND VERTICAL (2).
C     ROTARY KILNS USE 15-IN. W. G. VENTURI SCRUBBERS, VERTICAL USE MULTI-
C     CYCLONES.  KILN CAPACITIES IN TONS/HR., REGIONAL IN THOUSAND TONS/YR
C     EIGHTY PERCENT (80() CONTROL ON ROTARY KILNS ASSUMED FOR PROCESS
C     CONTROL.
C
      DIMENSION C1(2), E1(2), CAP(10), IUNIT(2,10), EFF(10), INPUT(12),
     1 REFF(10), A1(3,20), A2(3,20)
      COMMON A1, A2
C
C     INITIALIZE
C
      DO 10 I=1,12
      INPUT(I)=0
   10 CONTINUE
      READ 4999, A1, A2
 4999 FORMAT(10F8.0)
C
C     BEGIN INPUT WITH CARD TYPE 1.
C
   20 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      READ 5000, ICODE, IAUX, SCODE, RSAC1, RSAC2, TOTCAP, NPROC, IR,
     1 INPUT
 5000 FORMAT(1X,2I1,F2 0,A4,A1,F10.0,I2,1X,A3,4X,12A4)
      IF (ICODE-1) 2000,30,1000
   30 IF (SCODE-15.) 1010,40,1010
   40 IF (IAUX-1) 600,500,50
C
C     READ DETAILED PLANT DATA
C
   50 READ 5005, ICODE, SCODE, (IUNIT(1,I),IUNIT(2,I), EFF(I),CAP(I),
     1 I=1,NPROC)
 5005 FORMAT(1X,I1,1X,F2.0,5X,3(I2,I3,F2.0,F8.0,5X),/,(10X,I2,I3,F2.0,
     1 F8.0,5X,I2,I3,F2.0,F8.0,5X,I2,I3,F2.0,F8.0))
      IF (ICODE-2) 1020,60,1020
   60 IF (SCODE-15.) 1010,90,1010
C
C     CALCULATE REQUIRED EFFICIENCY
C
   90 DO 170 I=1,NPROC
      FACT=IUNIT(2,I)
      IF (CAP(I)-30.) 100,100,150
  100 REFF(I)=4.10*CAP(I)**0.66667
  105 IF (IUNIT(1,I)-1) 110,110,130
  110 REFF(I)=(CAP(I)*(1-REFF(I)))/(CAP(I)*.1)
      E=CAP(I)*.1
      IF (REFF(I)-EFF(I)) 170,170,120
  120 CALL VENTUR(CAP(I),REFF(I),AINV,AANN)
      GO TO 160
  130 REFF(I)=(CAP(I)*.01-REFF(I))/(CAP(I)*.01)
      E=CAP(I)*.01
      IF (REFF(I)-EFF(I)) 170,170,140
  140 CALL CWS(CAP(I),REFF(I),AINV,AANN)
      GO TO 160
  150 REFF(I)=55.0*(CAP(I)**0.11)-40.
      GO TO 105
  160 C1(1)=C1(1)+AINV*FACT
      C1(2)=C1(2)+AANN*FACT
      E1(1)=E1(1)+E*(1 -EFF(I)/100.)*FACT
      E1(2)=E1(2)+E*(1 -REFF(I))*FACT
  170 CONTINUE
      CALL OUTFI(RSAC1,RSAC2,AQCR,15,INPUT,C1,1,1,E1)
      GO TO 20
C
C   CALCULATIONS AS PER OU-455
C
  500 C1(1)=C1(1)+TOTCAP*94.46
      C1(2)=C1(2)+TOTCAP*65.83
      E1(1)=E1(1)+TOTCAP*.024
      E1(2)=E1(2)+TOTCAP*.00352
      CALL OUTFI(RSAC1,RSAC2,AQCR,15,INPUT,C1,1,1,E1)
       PRINT 6665, RSAC1, RSAC2, C1, E1
 6666 FORMAT(1X,A4,A1,4F15.2)
      GO TO 20
C
C   CALCULATIONS PLANT-BY-PLANT
C
  600 C1(1)=C1(1)+50.42
      C1(2)=C1(2)+69.08
      E1(1)=E1(1)+1209
      E1(2)=E1(2)+96.72
      CALL OUTFI(RSAC1,RSAC2,AQCR,15,INPUT,C1,1,1,E1)
       PRINT 6665, RSAC1, RSAC2, C1, E1
      GO TO 20
C
C   ERROR ROUTINES
C
 1000 PRINT 5025, ICODE
 5025 FORMAT(19H INVALID CARD CODE,,I4,  34H 1 EXPECTED.  SKIP TO NEXT 1
     1 CARD.)
      GO TO 20
 1010 PRINT 5030, SCODE
 5030 FORMAT(21H INVALID SOURCE CODE ,F4.2,23H.  SKIP TO NEXT 1 CARD.)
      GO TO 20
 1020 PRINT 5040, ICODE
 5040 FORMAT(19H INVALID CARD CODE ,I4,  23H.  SKIP TO NEXT 1 CARD.)
      GO TO 20
 2000 PRINT 5045
 5045 FORMAT(12H1GOOD FINISH)
 9999 STOP
      END
      SUBROUTINE CWS(C,R,A,B)
      DIMENSION A1(3,20)
      COMMON A1
      DO 40 I=1,20
      IF (A1(1,I)-C) 40,30,20
```

```
20 D=1.+(C-A1(1,I-1))/(A1(1,I)-A1(1,I-1))
   A=A1(2,I-1)*D
   B=A1(3,I-1)*D
   RETURN
30 A=A1(2,I)
   B=A1(3,I)
   RETURN
40 CONTINUE
   STOP
   END
   SUBROUTINE VENTUR(C,R,A,B)
   DIMENSION A1(3,20), A2(3,20)
   COMMON A2, A1
   DO 40 I=1,20
   IF (A1(1,I)-C) 40,30,20
20 D=1.+(C-A1(1,I-1))/(A1(1,I)-A1(1,I-1))
   A=A1(2,I-1)*D
   B=A1(3,I-1)*D
   RETURN
30 A=A1(2,I)
   B=A1(3,I)
   RETURN
40 CONTINUE
   STOP
   END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

# APPENDIX L

## Computer Program for Petroleum Products and Storage

# Appendix L

# Computer Program for Petroleum Products and Storage

## I. INTRODUCTION

The petroleum bulk storage plants emit hydrocarbons from gasoline storage tanks due to breathing and working losses and from tank vehicles due to working losses. This program is designed to run with ideal data; however, nonideal input can be adapted to the same format.

This appendix describes a computer program designed to compute the emissions and costs for controlling the emissions from the petroleum products and storage industry. Figure L-1 shows a general flow diagram of the program logic.

Section II lists the major assumptions and limitations in the computer program. Section III explains the program logic and includes tables showing input data with formats. A glossary of FORTRAN names used in the program is shown in Section IV and Section V is a listing of the computer program.

## II. ASSUMPTIONS

The major assumptions in regard to the calculations of emissions and control costs in the computer program are as follows:

a) All control tanks are equally effective.
b) All tanks are equally maintained and painted.
c) All tanks and tank vehicles with vapor recovery systems have zero working and breathing emissions.
d) All conservation tanks have zero working emissions.
e) There are no filling losses for conservation tanks.
f) The computer program limits the number of storage tanks per installation to 50 types and/or sizes.

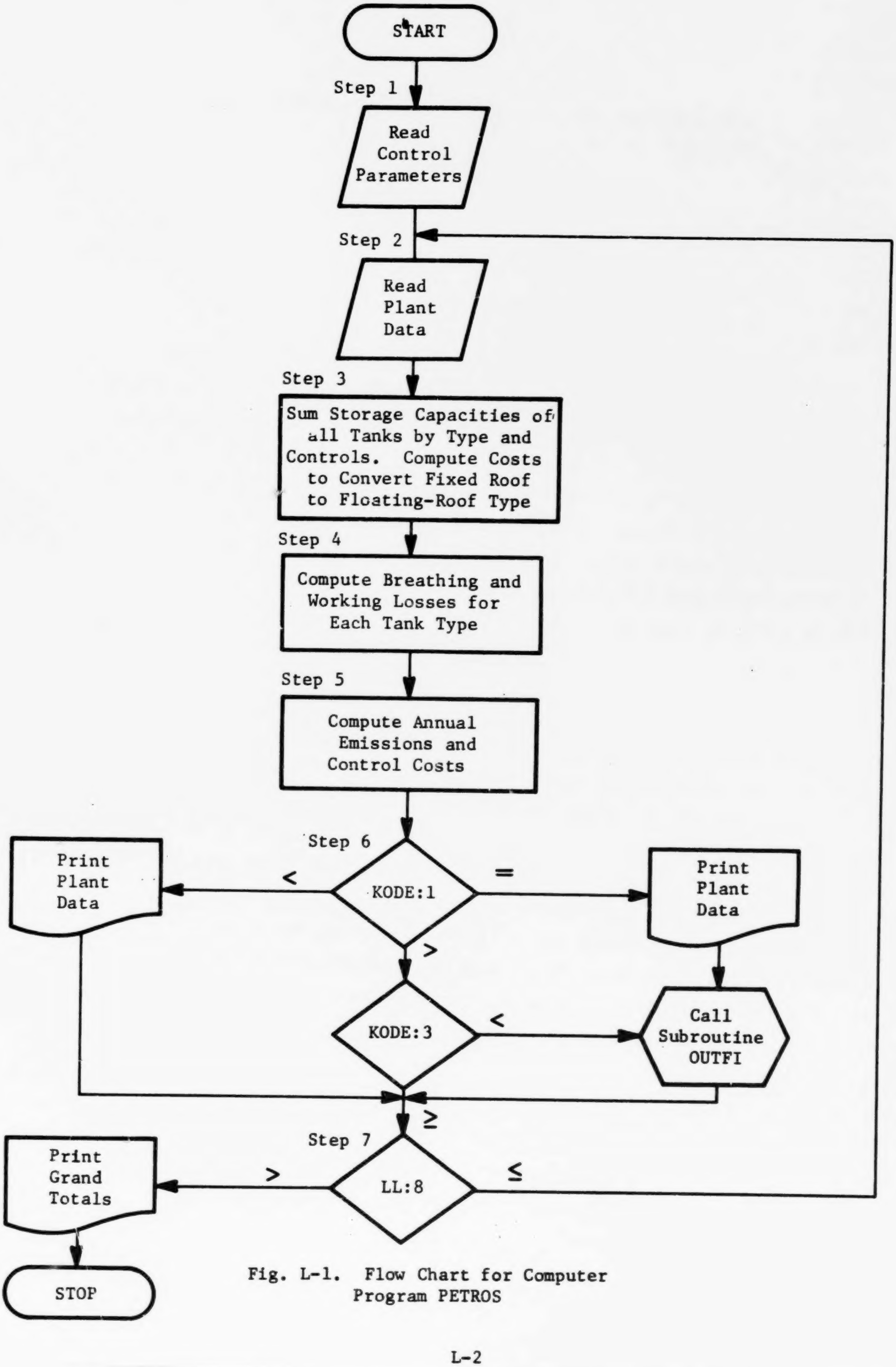

START
Step 1
Read Control Parameters
Step 2
Read Plant Data
Step 3
Sum Storage Capacities of all Tanks by Type and Controls. Compute Costs to Convert Fixed Roof to Floating-Roof Type
Step 4
Compute Breathing and Working Losses for Each Tank Type
Step 5
Compute Annual Emissions and Control Costs
Step 6
KODE:1
<
=
>
Print Plant Data
Print Plant Data
KODE:3
<
Call Subroutine OUTFI
≥
Step 7
LL:8
>
≤
Print Grand Totals
STOP

Fig. L-1. Flow Chart for Computer Program PETROS

## III. PROGRAM LOGIC

The FORTRAN names for the emissions from the petroleum products and storage facilities are EM3(1) for present emissions, and EM3(2) for controlled emissions. The investment and annual operating costs for individual installation are CO3(1) and CO3(2), respectively.

### Step 1.

Control parameters and tables as shown in Table L-1 are read in after the initialization of the FORTRAN parameters. These parameters remain constant throughout the entire program for all refineries but are input to enable the user to make changes when and if necessary.

### Step 2.

This is the beginning of a loop which reads in individual plant data consisting of at least two cards per plant. If the number of storage tanks is three or less, the number of data cards required is only two. One additional data card with the same format as card 2 is required for every three additional storage tanks thereafter, to be read in at the beginning of Step 3. Table L-2 shows the formats for these data.

### Step 3.

Step 3 begins with the last data card read in from Step 2. These data are for gasoline storage tanks or gasoline tank vehicles as denoted by IT(I). Other data are ITC(I) indicating type of controls, NIT(I) denoting number of storage tanks of input type IT(I), and SZ(I) denoting size of tank of type IT(I). I ranges from 1 to NFL which is limited to 3. A DO loop with I equal to 1 to NFL is then entered. Subroutine FIND is called in order to return the investment cost for all fixed roof gasoline storage tanks, according to the size of the tank. These costs are summed in CO3(1).

The total capacities (1000 bbl.) of tanks with various types of controls are summed as the program progresses thru the loop. The value of "LL" is then checked to determine if there are more data; if so, the program loops back to read in more data until all data for that plant have been processed. This is indicated by an "8" for the value of LL. The emissions of hydrocarbons resulting from both the breathing and working loss from all storage tanks are then computed.

Step 4.

The annual throughput of gasoline (1000 bbl.) is required in order to compute the emissions from breathing and working losses. The throughput from storage tanks, GASV, is computed as:

$$\mathrm{GASV} = \mathrm{TOR} \times \sum_{n=1}^{n=3} \mathrm{GST}_n$$

where:

$GST_1$ is total volume (1000 bbl.) for all fixed roof storage tanks, without vapor recovery, splash filled;

$GST_2$ is total volume (1000 bbl.) for all conservation storage tanks, without vapor recovery;

$GST_3$ is total volume for all fixed roof storage tanks without vapor recovery, submerged filled; and

TOR is the turnover rate for storage tanks previously computed as 365.0/DAY2, where DAY2 is the number of days supply stored at each facility.

The turnover rates for gasoline tank vehicles are required in order to compute the throughput. These rates are computed for each type as follows:

Splash filled:

$$\mathrm{TGTV1} = (\mathrm{GASV} \div \mathrm{GTV}_1) \times \mathrm{PCT}_1 .$$

Submerged filled:

$$\mathrm{TGTV2} = (\mathrm{GASV} \div \mathrm{GTV}_2) \times \mathrm{PCT}_2$$

where:

$GVT_1$ is the total volume (1000 bbl.) for all gasoline tank vehicles without vapor recovery, splash filled;

$GVT_2$ is the total volume (1000 bbl.) for all gasoline tank vehicles without vapor recovery, submerged filled; and

$PCT_1$ and $PCT_2$ are the ratio of each type to the total volume of both types.

The breathing and working losses are then computed using the appropriate emission factor for each type of tank.

Step 5.

The emissions from all tanks are summed in order to print out the emissions in 1000 tons for each facility. The costs were summed in Step 3 following each call of Subroutine FIND.

The final calculation in Step 5 consists of summing the costs and emissions for output of grand totals.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

Step 7.

The program checks the 3rd plant data card for an "8" or "9" punched in LL (Column 71,72). If the value for LL is "8," the program returns control to Step 3 where the process is resumed with subsequent plant until a "9" appears in the "LL" column. When the value for LL is "9," the program prints the total costs and emissions, if applicable, and terminates.

TABLE L-1. - CONTROL PARAMETERS FOR PROGRAM PETROS

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Denotes when to print plant data and when to bypass Subroutine OUTFI. | 1-5 | I5 |
| | Card 2 | | |
| FA | Gasoline storage tank emission factor (breathing loss) for fixed roof tanks without vapor recovery, splash and submerged filled. | 1-10 | F10.4 |
| FB | Gasoline storage tank emission factor (working loss) for fixed roof without vapor recovery and splash fill. | 11-20 | F10.4 |
| DC | Emission factor (working loss) for gasoline tank vehicle without vapor recovery, splash fill. | 21-30 | F10.4 |
| FD | Gasoline storage tank emission factor (breathing loss) for conservation tank without vapor recovery. | 31-40 | F10.4 |
| FE | Gasoline storage tank emission factor (working loss) for fixed roof without vapor recovery, submerged filled. | 41-50 | F10.4 |
| FF | Gasoline tank vehicle without vapor recovery submerged filled (working loss) emission factor. | 51-60 | F10.4 |
| | Card 3 | | |
| TABLE(I, J) | Table (1,J) is tank capacity (1000 bbl.), and Table (2,J) is the cost ($1,000) for installing a floating roof for the J-th capacity. | 1-60 | 12F5.0 |

TABLE L-2. - PLANT DATA FOR PROGRAM PETROS

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| NCO | Card type. | 1-2 | I2 |
| NS | Source number. | 3-5 | I3 |
| RSAC | National location code. | 6-9 | A4 |
| | Blank. | 10 | 1X |
| TOTCAP | Crude capacity (1000 bbls/cd). | 11-20 | F10.2 |
| | Blank. | 21-25 | 5X |
| DAY2 | Number of days supply of gasoline stocked. | 26-30 | F5.2 |
| INP(I) | Name and location or refinery. | 31-78 | 12A4 |
| | Blank. | 79-80 | 2X |
| | Card 2 | | |
| NCO | Card number or type. | 1-2 | F2 |
| NFL | Number of data fields on card. (1-3) | 3-5 | I3 |
| LOC | National location code. | 6-9 | A4 |
| | Blank. | 10 | 1X |
| IT(I) | Input type as follows:<br>1 - denotes uncontrolled crude oil tanks.<br>2 - denotes uncontrolled gasoline tanks. | 11-12 | I2 |
| ITC(I) | Indicates type of control as follows:<br>1 - fixed roof tank - if gasoline without vapor recovery and splash fill.<br>2 - conservative tank and without vapor recovery if gasoline.<br>3 - fixed roof without vapor recovery, submerged filled. | 13-14 | I2 |

TABLE L-2. - PLANT DATA FOR PROGRAM PETROS (Continued)

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| NIT(I) | Number of type IT. | 15-17 | I3 |
| SZ(I) | Size of uncontrolled tank of type IT. | 18-25 | F8.2 |
|  | Blank. | 26-30 | 5X |
| Same as 11-30 above with I = 2. |  | 31-50 |  |
| Same as 11-30 above with I = 3. |  | 51-70 |  |
| LL | An "8" in this space indicates the end of data for the current plant. A "9" denotes the last data card for the last plant. | 71-72 | I2 |

## IV. GLOSSARY OF FORTRAN NAMES FOR PROGRAM PETROS

| FORTRAN Name | Definition |
|---|---|
| ANS(2) | Interpolated value from Subroutine FIND representing cost to install floating roof. |
| BLC | Controlled hydrocarbon emissions (tons/yr.) due to breathing losses. |
| BLCO | Hydrocarbon emissions (tons/yr.) due to breathing losses from crude oil storage tanks. |
| BLGS | Hydrocarbon emissions (tons/yr.) due to breathing losses from gasoline storage tanks. |
| COST(2) | Sum of investment and annual costs. |
| COUNT | Number of tanks of type IT(I). |
| CO3(2) | Investment and annual costs for controlling hydrocarbons. |
| DAY2 | Number of days supply of gasoline stocked. |
| EMIS(2) | Sum of emissions for all plants for the 4 types of emissions before and after controls. |
| EM3(2) | Hydrocarbon emissions before and after controls. |
| FA | Breathing loss emission factor (tons/yr./1000 bbls.) for gasoline storage tank with fixed roof, without vapor recovery, splash and submerged filled. |
| FB | Working loss emission factor (tons/1000 bbls.) for gasoline storage tank with fixed roof, without vapor recovery, splash filled. |
| FC | Working loss emission factor (tons/1000 bbls.) for gasoline tank vehicle without vapor recovery, splash filled. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| FD | Breathing loss emission factor (tons/yr./1000 bbls.) for gasoline storage tank, conservation type, without vapor recovery. |
| FE | Working loss emission factor (tons/1000 bbls.) for gasoline storage tank with fixed roof, without vapor recovery, submerged filled. |
| FF | Working loss emission factor (tons/1000 bbls.) for gasoline tank vehicle without vapor recovery, submerged filled. |
| FIND | A subroutine used to return linearly interpolated values from any input table. |
| GASV | Total annual gasoline throughput, 1000 bbl. |
| GST(3) | Storage capacity (1000 bbl.) for gasoline storage tanks of type ITC(I). |
| GTV(3) | Storage capacity (1000 bbl.) for gasoline tank vehicles of type ITC(I). |
| IAQ | Dummy variable used in calling Subroutine OUTFI. |
| ICODE | Dummy variable used in calling Subroutine OUTFI. |
| IN | The I-th column of Table (I,J) from which an interpolated value is to be returned from Subroutine FIND. |
| INC | The incremental value used to determine the I-th vector of Table (I,J) when calling Subroutine FIND. |
| INP(12) | Name and location of plant. |
| IT(50) | Input value denoting the type of the I-th uncontrolled tanks. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| ITC(50) | Input value denoting the types of controls on the tank type IT(I). |
| KODE | Input value to determine when to bypass Subroutine OUTFI and/or the printout of plant data. |
| LIM | The I-th number of values in Table (I,J). |
| LL | An input variable denoting the last data card for a plant and/or the last data card for all plants. |
| LOC | National location code. |
| MAX | The J-th number of values in Table (I,J). |
| NCO | The card number or card type for a plant. |
| NE | The number of emissions from the source. |
| NFL | The number of data fields on the card being read in. |
| NIT(50) | Variable denoting the number of tanks of input type I. |
| NPLT | The number of the plant being processed in sequential order. |
| NS | The numerical value assigned to this source. |
| OST(3) | Storage capacity (1000 bbl.) for crude oil storage tanks of type ITC(I). |
| PCT | The percentile of crude oil throughput. |
| PCT1 | Ratio of gasoline tank vehicle without vapor recovery, splash filled. |
| PCT2 | Ratio of gasoline tank vehicle without vapor recovery, submerged filled. |
| RSAC | National location code. |
| SUM1 | The sum of the investment costs from all pollutants and all plants. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| SUM2 | The sum of the annual operating costs from all pollutants and all plants. |
| SZ(50) | Size of storage tank of type IT(I) in thousands of barrels. |
| TABLE(2,6) | Input table giving cost ($1000) for installing a floating roof in tank having J-th capacity (1000 bbls.). |
| TEMP1 | Equated to SZ(I) in loop in order to return costs from Subroutine FIND. |
| TGTV1 | Turnover rate for gasoline tank vehicle without vapor recovery, splash filled. |
| TGTV2 | Turnover rate for gasoline tank vehicle without vapor recovery, submerged filled. |
| TOR | The annual gasoline turnover rate for storage tanks in a given plant. |
| TOTCAP | Crude oil capacity of refinery (1000 bbls.). |
| WLC | Controlled hydrocarbon emissions (tons/yr.) due to working losses. |
| WLGS | Hydrocarbon emissions (tons/yr.) due to working losses from gasoline storage tanks. |
| WLGT | Hydrocarbon emissions (tons/yr.) due to working losses from gasoline tank vehicles. |

# V. LISTING OF COMPUTER PROGRAM FOR PETROLEUM PRODUCTS AND STORAGE

```
C      PROGRAM PETROS
C         THIS PROGRAM COMPUTES EMISSIONS AND CONTROL COSTS FOR PETROLEUM
C           PRODUCTS AND STORAGE FACILITIES. THE EMISSIONS ARE
C               EM3(I) -HYDROCARBONS
       INTEGER RSAC
       INTEGER CO3
       DIMENSION INP(12),IT(50),ITC(50),SZ(50),GTV(3) ,TABLE(2,6),CO3(2),
      2ANS(2),EM3(2),EMIS(2),NIT(50),GST(3)
       ICODE = 0
       IAQ = 0
       NPLT = 0
       NE = 1
       SUM1 = 0.
       SUM2 = 0.
       EMIS(1) = 0.
       EMIS(2) = 0.
C        . READ IN KODE TO DETERMINE THE FOLLOWING
C           KODE VALUE  PLANT DATA  CALL OUTFI
C           ---------   ----------  ----------
C               0          YES          NO
C               1          YES          YES
C               2          NO           YES
C               3          NO           NO
       READ 610, KODE
C         READ IN TABLE OF COST($1000) VERSUS TANK CAPACITY (1000 BBL.)
C           IN ORDER TO DETERMINE COST TO INSTALL FLOATING ROOF.
       READ 620, FA, FB, FC, FD, FE, FF
       READ 600,  (TABLE(1,J), TABLE(2,J), J = 1,6)
 5     CONTINUE
       LL = 0
       DO 6 I = 1,3
       GTV(I) = 0.
       GST(I) = 0.
 6     OST(I) = 0.
 10    CONTINUE
       READ 630, NCO,NS, RSAC,TOTCAP,      DAY2,(INP(I),I = 1,12)
       NPLT = NPLT +1
       DO 11 J = 1,2
       EM3(J) = 0.
       CO3(J)=0.
 11    CONTINUE
 12    CONTINUE
       READ 650,NCO,NFL,LOC,( IT(I),ITC(I),NIT(I),SZ(I)           ,I=1,3),LL
C         LOC IS THE NATIONAL LOCATION CODE AND SHOULD BE THE SAME AS
C           RSAC IN READ 630.
C         IT(I) DENOTES THE INPUT TYPE WHERE 2 DENOTES GASOLINE STORAGE
C           TANKS AND 3 DENOTES GASOLINE TANK VEHICLES.
C         ITC(I) INDICATES THE TYPE OF CONTROLS AS FOLLOWSO
C           1 - FIXED ROOF TANK; IF GASOLINE W.O. VAPOR RECOVERY, SPLASH
C           FILLED.
C           2 FOR CONSERVATION TANKS AND W.O. VAPOR RECOVERY.
C           3 FOR FIXED ROOF W.O. VAPOR RECOVERY, SUMERGE FILLED.
```

```
C         NIT(I) DENOTES THE NUMBER OF TANKS OF INPUT TYPE I.
C         SZ(I) DENOTES THE SIZE OF THE UNCONTROLLED TANK OF TYPE IT.
C         GTV(I) = TOTAL STORAGE FOR ALL GASOLINE TANK VEHICLES, 1000 BBL.
C         GST(I) = TOTAL STORAGE FOR ALL GASOLINE STORAGE TANKS.
C         *****
C         COMPUTE THE TURNOVER RATE, TOR, FOR GASOLINE STORAGE TANKS.
      TOR = 365.0 /DAY2
      DO 100 I = 1,NFL
      TEMP1 = SZ(I)
      LIM = 2
      MAX = 6
      IN = 2
      INC = 1
      COUNT = NIT(I)
      IF(IT(I)-2)50,60,96
C         *****
 50   PRINT 660
      GO TO 100
C      THE FOLLOWING COMPUTATIONS ARE FOR GASOLINE STORAGE TANKS.
 60   IF(ITC(I)-2)70,80,90
C         FIXED ROOF, W O. VAPOR RECOVERY, SPLASH FILL.
 70   GST(1) = GST(1) + SZ(I) * COUNT
      CALL FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
      CO3(1) =    ANS(2) + CO3(1)
      GO TO 100
C         CONSERVATION, W.O. VAPOR RECOVVERY.
 80   GST(2) = GST(2) + SZ(I) * COUNT
      GO TO 100
C         FIXED ROOF, W O. VAPOR RECOVERY SUBMERGE FILL
 90   GST(3) = GST(3) + SZ(I) * COUNT
      CALL FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
      CO3(1) =    ANS(2) + CO3(1)
C         *****
      GO TO 100
C      THE FOLLOWING COMPUTATIONS ARE FOR GASOLINE TANK VEHICLES.
 96   IF(ITC(I)-2)97,98,50
C         W/VAPOR RECOVERY, SPLASH FILL
 97   GTV(1) = GTV(1) + SZ(I) * COUNT
      GO TO 100
C         W.O  VAPOR RECOVERY, SUBMERGE FILL
 98   GTV(2) = GTV(2) + SZ(I) * COUNT
 100  CONTINUE
      IF(LL-8)12,110,110
 110  CONTINUE
C         COMPUTE THE ANNUAL THROUGHPUT OF GASOLINE (1000BBL.).
      GASV = TOR * (GST(1) + GST(2) + GST(3))
C         COMPUTE THE RATIO OF GASOLINE TANK VEHICLES  WITH SPLASH
C            FILL (PCT1), AND THE RATIO WITH SUBMERGE FILL (PCT2).
      PCT1 = GTV(1) / (GTV(1) + GTV(2))
      PCT2 = GTV(2) / (GTV(1) + GTV(2))
C         COMPUTE THE TURNOVER FOR GASOLINE TANK VEHICLES.
      TGTV1 = (GASV/GTV(1)) * PCT1
      TGTV2 = (GASV/GTV(2)) * PCT2
C         COMPUTE BREATHING LOSSES, TONS/YR. FOR GASOLINE STORAGE TANKS.
      BLGS = FA * (GST(1) + GST(3)) + FD * GST(2)
C         COMPUTE THE CONTROLLED EMISSIONS DUE TO BREATHING LOSSES.
      BLC =0.87 * (GST(1) +GST(2) + GST(3))
C         BREATHING LOSSES FROM GASOLINE TANK VEHICLES IS ZERO.
C         *****
```

```
C          COMPUTE WORKING LOSSES, TONS/YEAR FOR GASOLINE STORAGE
C             TANKS AND GASOLINE TANK VEHICLES.
      WLGS = (FB * GST(1) + FE * GST(3)) * TOR
      WLGT=FC*GTV(1)*TGTV1 + FF*GTV(2)*TGTV2
C          COMPUTE THE CONTROLLED EMISSIONS DUE TO WORKING LOSSES.
      WLC=0.152*TOR*(GST(1)+GST(2))+0.102*(GTV(1)*TGTV1+GTV(2)*TGTV2)
C          *****
C          COMPUTE TOTAL HYDROCARBON EMISSIONS FROM ALL STORAGE TANKS AND
C             TANK VEHICLES IN 1000 TONS/YEAR.
      EM3(1) = (BLGS +          WLGS + WLGT)/1000.0
      EM3(2) = EM3(2) + (BLC + WLC)/1000.
C          * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C          THIS ENDS THE COMPUTATIONS OF HYDROCARBONS FROM STORAGE FACILI.
      EMIS(1) = EMIS(1) + EM3(1)
      EMIS(2) = EMIS(2) + EM3(2)
      SUM1 = SUM1 + CO3(1)
      SUM2 = SUM2 + CO3(2)
      IF(KODE-1)200,210,220
  200 CONTINUE
C          PRINT PLANT DATA.
      PRINT 760, NPLT,EM3(1),EM3(2),CO3(1), CO3(2)
      GO TO 5
  210 CONTINUE
      PRINT 760, NPLT,EM3(1),EM3(2),CO3(1), CO3(2)
      IF(KODE - 3)220,250,250
  220 CONTINUE
      CALL OUTFI (RSAC,ICODE,IAQ,NS,INP,COST,NE,1,EM1,2,EM2,3,EM3,4,EM4)
  250 CONTINUE
      IF(LL-8)5,5,300
  300 CONTINUE
C          PRINT GRAND TOTALS AND END PROGRAM.
C
      PRINT 770, EMIS(1),EMIS(2),SUM1,SUM2
  600 FORMAT (12F5.0)
  610 FORMAT (I5)
  620 FORMAT (6F10.4)
  630 FORMAT (I2,I3,A4,1X,F10.2, 5X,F5.1  ,12A4)
  640 FORMAT (10X,2I2,F6.2,2F10.3)
  650 FORMAT (I2,I3,A4,1X,3(2I2,I3,F8.2, 5X ),I2)
  660 FORMAT (37H ERROR IN INPUT DATA,IT(I) OR ITC(I).)
  760 FORMAT (I3,1X,4F12.2)
  770 FORMAT (4X,4F12.2)
      STOP
      END

      SUBROUTINE FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
C           THE PURPOSE OF THE SUBROUTINE IS TO DO A TABLE LOOKUP
C              FOR ANY TABLE(I,J) BASED ON THE FOLLOWING
C                   I = 1,LIM
C                   J = 1,MAX
C                   TEMP1 IS THE PARAMETER FOR WHICH VALUES ARE FOUND
C                   ANS(I) IS THE INTERPOLATED VALUE FOR TEMP1
C                   IN IS THE BEGINNING OF I
C                   INC IS THE INCREMENT OF I
      DIMENSION TABLE(2,6),ANS(2)
      IF (TEMP1-TABLE(1,1))5,5,6
    5 CONTINUE
      DO 4 I = IN,LIM,INC
    4 ANS(I) = TABLE(I,1)
```

```
      GO TO 60
6     CONTINUE
      IF(TEMP1-TABLE(1,MAX))9,9,8
8     PRINT 100
100   FORMAT(48H PLANT SIZE IS LARGER THAN MAXIMUM SIZE IN TABLE,//)
      DO 7 I = IN,LIM,INC
7     ANS(I) = TABLE(I,MAX)
      GO TO 60
9     CONTINUE
      DO 30 J = 1,MAX
      IF (TEMP1-TABLE(1,J))10,20,30
   10 RATIO = (TEMP1-TABLE(1,J-1)) /(TABLE(1,J) - TABLE(1,J-1))
      JJ = J
      GO TO 40
   20 RATIO = 1.0
      JJ = J
      GO TO 40
   30 CONTINUE
   40 DO 50 I = IN,LIM,INC
   50 ANS(I) = RATIO *(TABLE(I,JJ)-TABLE(I,JJ-1)) + TABLE(I,JJ-1)
60    CONTINUE
      RETURN
      END
```

```
 INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS


   0
   8.5        0.2420      0.1720      0.8700      0.1520      0.1020
   0    14    25    20    50    32    75    45   100    68   200   160
```

# APPENDIX M

## Computer Program for Petroleum Refining

# Appendix M

## Computer Program for Petroleum Refining

### I. INTRODUCTION

The petroleum refining industry contributes to air pollution by emitting carbon monoxide, hydrocarbons, particulates, and sulfur oxides from catalyst regeneration; sulfur dioxide from the combustion processes; and more hydrocarbons from storage facilities.

The purpose of this report is to describe a computer program designed to compute the emissions and associated costs for controlling the emissions inherent to a model firm of the petroleum refining industry. This program, REFINE, is designed to run with ideal data; however, non-ideal data are adaptable. Figure M-1 shows a general flow diagram of the program logic.

Section II lists the major assumptions and limitations in the computer program. Section III explains the program logic and includes tables that show input data in a format that enables one to use the program. Section IV is a listing of the FORTRAN names used and Section V is a listing of the computer program.

### II. MAJOR ASSUMPTIONS

The major assumptions made in regard to the calculations of emissions and control costs in the computer program are as follows:

a) The sizes of the carbon monoxide heat boilers, if present, are assumed to be sufficient to accomodate the specific refinery.

b) All control tanks are equally effective.

c) Ambient temperatures are constant for all regions.

d) All tanks are equally maintained and painted.

e) All tanks and tank vehicles with vapor recovery systems have zero working and breathing emissions.

f) All conservations tanks and all crude oil tanks have zero working emissions.

g) The computer program dimension statements limit the number of storage tanks per installation to 50 types and/or sizes.

h) There are no filling losses for conservation tanks.

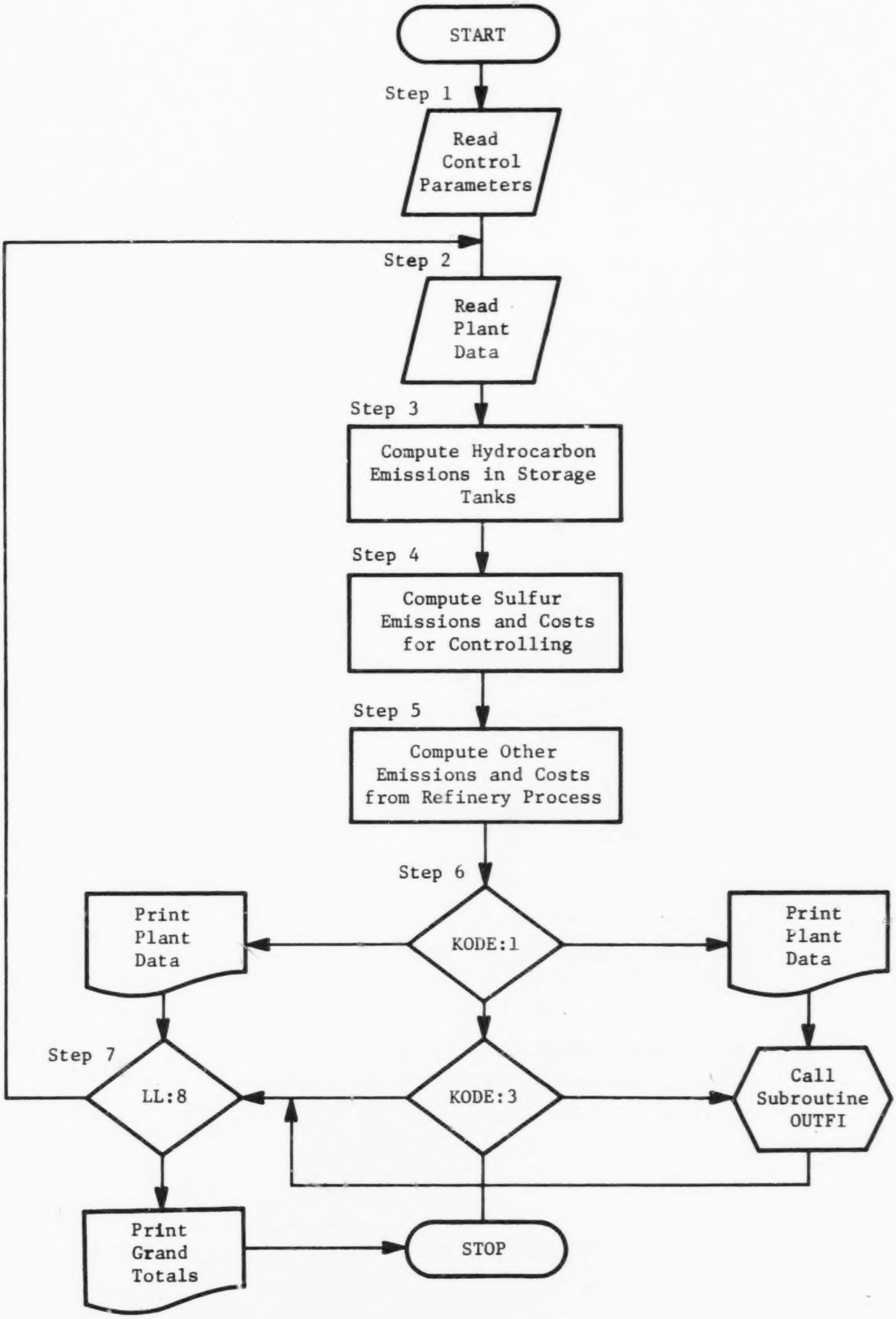

START
Step 1
Read Control Parameters
Step 2
Read Plant Data
Step 3
Compute Hydrocarbon Emissions in Storage Tanks
Step 4
Compute Sulfur Emissions and Costs for Controlling
Step 5
Compute Other Emissions and Costs from Refinery Process
Step 6
KODE:1
Print Plant Data
Print Plant Data
Step 7
LL:8
KODE:3
Call Subroutine OUTFI
Print Grand Totals
STOP

Fig. M-1. Flow Chart of Program REFINE.

## III. PROGRAM LOGIC

The FORTRAN names for the emissions from oil refineries are as follows:

1) EM1(I) for particulates,
2) EM2(I) for sulfur oxides,
3) EM3(I) for hydrocarbons, and
4) EM4(I) for carbon monoxides.

This program is designed to compute the emissions and the investment and annual operating costs, COST (I), for the oil refining industry. Other FORTRAN names with definitions are listed in Section IV.

Step 1.

Control parameters and tables are read in after initiating the FORTRAN parameters. These parameters remain constant throughout the entire program for all refineries but are used as an input to enable the programmer to make changes when and if necessary. Table M-1 lists these parameters with the FORTRAN format and definitions.

Step 2.

This is the beginning of a loop which reads in individual plant data consisting of at least three cards each. If the number of storage tanks is three or less, the number of data cards required is only three. One additional data card is required for every three additional storage tanks thereafter--read in at the beginning of Step 3. See Table M-2 for a list of these input data with formats and definitions.

Step 3.

Step 3 begins with the last data card read in from Step 2. These data are for crude oil storage tanks, gasoline storage tanks or gasoline tank vehicles as denoted by IT(I). Other data are ITC(I) indicating type of controls, NIT(I) denoting number of storage tanks of input type IT(I), and SZ(I) denoting size of tank of type IT(I). I ranges from 1 to NFL which is limited to 3. A DO loop with I equal to 1 to NFL is then entered. Subroutine FIND is called in order to return the investment cost, ANS(2), for all fixed roof gasoline and crude oil storage tanks and in accordance to the size of the tank. These costs are summed in CO3(1).

TABLE M-1. - CONTROL PARAMETERS FOR PROGRAM REFINE

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Denotes when to print plant data and when to bypass Subroutine OUTFI. | 1-5 | I5 |
| | Card 2 | | |
| FA | Gasoline storage tank emission factor (working loss) for fixed roof without vapor recovery and splash fill. | 1-10 | F10.4 |
| FB | Gasoline storage tank emission factor (working loss) for fixed roof without vapor recovery and splash fill. | 11-20 | F10.4 |
| DC | Emission factor (working loss) for gasoline tank vehicle without vapor recovery and splash fill. | 21-30 | F10.4 |
| FD | Gasoline storage tank emission factor (breathing loss) for conservation tank without vapor recovery. | 31-40 | F10.4 |
| FE | Gasoline storage tank emission factor (working loss) for fixed roof without vapor recovery and submerged fill. | 41-50 | F10.4 |
| FF | Gasoline tank vehicle without vapor recovery submerged fill (working loss) emission factor. | 51-60 | F10.4 |
| FG | Emission factor (breathing loss) for crude oil storage tank with fixed roof. | 61-70 | F10.4 |
| FH | Crude oil conservation storage tank (breathing loss) emission factor. | 71-80 | F10.4 |
| | Card 3 | | |
| TABLE(I,J), (I=1,2, J=1,6) | Table (1,J) is tank capacity (1000 bbls.), and Table (2,J) is the cost ($1,000) for installing a floating roof for the J-th capacity. | 1-60 | 12F5.0 |

TABLE M-2. - PLANT DATA FOR PROGRAM REFINE

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| NCO | Card type. | 1-2 | I2 |
| NS | Source number. | 3-5 | I3 |
| RSAC | National location code. | 6-9 | A4 |
| | Blank. | 10 | 1X |
| TOTCAP | Crude capacity (1000 bbls/cd). | 11-20 | F10.2 |
| DAY1 | Number of days supply of crude oil stocked. | 21-25 | F5.1 |
| DAY2 | Number of days supply of gasoline stocked. | 26-30 | F5.2 |
| INP(I) | Name and location of refinery. | 31-78 | 12A4 |
| | Blank. | 79-80 | 2X |
| | Card 2 | | |
| Same as 1-10 in Card No. 1. | | 1-10 | |
| ITYP | Type of catalytic cracking unit.* | 11-12 | I2 |
| COB | Denotes presence of CO boiler. | 13-14 | I2 |
| SULFA | Factor to determine amount of sulfur that could be recovered. | 15-20 | F6.2 |
| CAT | Catalytic cracking (1000 bbls/cd). | 21-30 | F10.3 |
| SUR | Sulfur recovery, tons/day | 31-40 | F10.3 |
| | Blank. | 41-80 | 40X |

* Types of catalytic cracking units:

0 - Normal process controls without electrostatic precipitator.
1 - Normal process controls with electrostatic precipitator.
2 - Thermofor catalyst unit (TCC).
3 - Houdriflow unit (HCC).

TABLE M-2. - PLANT DATA FOR PROGRAM REFINE (continued)

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 3 | | |
| NCO | Type of card. | 1-2 | I2 |
| NFL | Number of data fields on card. (1-3) | 3-5 | I3 |
| LOC | National location code. | 6-9 | A4 |
| | Blank. | 10 | 1X |
| IT(I) | Input type as follows:<br>1 - denotes uncontrolled crude oil tanks.<br>2 - denotes uncontrolled gasoline tanks. | 11-12 | I2 |
| ITC(I) | Indicate type of control as follows:<br>1 - fixed roof tank--if gasoline tank without vapor recovery and splash fill.<br>2 - conservation tank and without vapor recovery--if gasoline tank.<br>3 - fixed roof tank without vapor recovery and submerged fill. | 13-14 | I2 |
| NIT(I) | Number of type IT. | 15-17 | I3 |
| SZ(I) | Size of uncontrolled tank of type IT. | 18-25 | F8.2 |
| | Blank. | 26-30 | 5X |
| same as 11-30 above with I = 2. | | 31-50 | |
| same as 11-30 above with I = 3. | | 51-70 | |
| An "8" in this space indicates the end of data for the current plant. A "9" denotes the last data card for the last plant. | | 71-72 | I2 |

The total capacities (1000 bbls.) of tanks with various types of controls are summed as the program progresses through the loop. The value of "LL" is then checked to determine if there are more data in which case the program loops back to read in more data until all data for that plant has been processed. This is indiated by an "8" for the value of LL. The emissions of hydrocarbons resulting from both the breathing and working loss from all storage tanks are then computed.

Step 4.

The total amount of sulfur, S (tons/day), which can be recovered is required in order to compute the investment costs and emissions from sulfur recovery plants. There are no annual operating costs since sulfur recovery tends to be a breakeven or profitable operation.

To compute the sulfur dioxide emissions without specific data on the composition of the refinery's crude oil or its exact processing techniques, an emission factor of 50 tons per 100 thousand barrels of crude oil throughput was used. Therefore, the processed emissions, 1000 tons/yr., are computed as:

$$\mathrm{EM2(1)} = \left(50.0 \times \frac{\mathrm{COIL}}{100} - \mathrm{SUR} \times 360.0\right)/1000.$$

where COIL is the throughput of crude oil in thousands of barrels per day and SUR is the amount of sulfur in tons per day recovered. The controlled emissions in 1000 tons per year are computed as:

$$\mathrm{EM2(2)} = \left(530.0 \times \mathrm{S}\right)/1000.$$

Step 5.

The emissions from catalytic cracking are particulates, EM1; hydrocarbons, EM3; and carbon monoxide, EM4. These emissions and costs for controlling these emissions are computed in Step 5.

The first computations are the investment and annual operating costs for controlling particulates.

The emissions are calculated according to the type of catalytic cracking unit, ITYP. If ITYP is less than one, the catalytic cracking is a normal process without an electrostatic precipitator. When ITYP is one, the catalytic cracker has normal process controls with an electrostatic precipitator. A 2 or 3 for ITYP indicates a Thermofor catalyst unit and Houdriflow unit respectively. The emissions before and after controls for particulates, EM1, are calculated regardless of the type of controls. The controlled emissions for hydrocarbons and carbon monoxides are assumed to be zero. Uncontrolled hydrocarbon emissions, EM3(1), are based on 180 pounds HC per 1000 barrels total feed for fluid units (ITYP = 0 and 1), and 57 pounds HC per 1000 barrels total feed from Thermofor units (ITYP = 2). The uncontrolled carbon monoxide emissions are based on 5.6 tons of CO per 1000 barrels total feed from normal process units. Uncontrolled emissions from Thermofor units are based on 1.2 tons of CO per 1000 barrels total feed.

There are no carbon monoxide or hydrocarbon emissions computed from Houdriflow units since they are all presently controlled.

The presence of CO boilers indicates a 99 percent control of hydrocarbons and carbon monoxide from the refinery process.

The calculation in Step 5 consists of summing the costs and emissions for an output of grand totals.

Step 6.

The value of KODE determines when plant data are printed out and when Subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

Step 7.

The program checks the 3rd plant data card for an "8" or a "9" punched in LL (Column 71,72). If the value for LL is "8," the program returns control to Step 3 where the process is resumed with subsequent plants until a "9" appears in the "LL" column. When the value for LL is "9," the program prints the total costs and emissions and terminates.

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| ANS(2) | Interpolated value from Subroutine FIND representing cost to install floating roof. |
| BLC | Controlled hydrocarbon emissions (tons/yr.) due to breathing losses. |
| BLCO | Hydrocarbon emissions (tons/yr.) due to breathing losses from crude oil storage tanks. |
| BLGS | Hydrocarbon emissions (tons/yr.) due to breathing losses from gasoline storage tanks. |
| CAT | Capacity of catalytic cracker in 1000 b/cd. |
| CCAT | Annual capacity of catalytic cracker in 1000 barrels of oil. |
| COB | A "1" for this variable denotes the presence of a CO boiler. |
| COIL | Crude oil throughput, (1000 b/cd). |
| COST(2) | Total investment and annual costs for a plant. |
| COUNT | Number of tanks of type IT(I). |
| COT | Crude oil annual turnover rate. |
| CO1(2) | Investment and annual costs for controlling particulates. |
| CO2(2) | Investment and annual costs for controlling sulfur oxides. |
| CO3(2) | Investment and annual costs for controlling hydrocarbons. |
| CO4(2) | Investment and annual costs for controlling carbon monoxide. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| DAY1 | Number of days supply of crude oil stocked. |
| DAY2 | Number of days supply of gasoline stocked. |
| EMIS (4,2) | Sum of emissions for all plants for the four types of emissions before and after controls. |
| EM1(2) | Emissions before and after controls for particulates. |
| EM2(2) | Emissions before and after controls for sulfur oxides. |
| EM3(2) | Emissions before and after controls for hydrocarbons. |
| EM4(2) | Emissions before and after controls for carbon monoxide. |
| FA | Breathing loss emission factor (tons/yr./1000 bbls.) for gasoline storage tank with fixed roof, without vapor recovery, splash and submerged fill. |
| FB | Working loss emission factor (tons/1000 bbls.) for gasoline storage tank with fixed roof, without vapor recovery and splash fill. |
| FC | Working loss emission factor (tons/1000 bbls.) for gasoline tank vehicle without vapor recovery and splash fill. |
| FD | Breathing loss emission factor (tons/yr./1000 bbls.) for gasoline storage tank, conservation type, without vapor recovery. |
| FE | Working loss emission factor (tons/1000 bbls.) for gasoline storage tank with fixed roof, without vapor recovery and submerged fill. |
| FF | Working loss emission factor (tons/1000 bbls.) for gasoline tank vehicle without vapor recovery and submerged fill. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| FG | Breathing loss (tons/yr/1000 bbls.) for crude oil storage tank with fixed roof. |
| FH | Breathing loss (tons/yr/1000 bbls.) for crude oil storage tank with conservation roof. |
| FIND | A subroutine used to return linearly interpolated values from any input table. |
| GASV | Total annual gasoline throughput, 1000 bbls. |
| GST(3) | Storage capacity (1000 bbls.) for gasoline storage tanks of type ITC(I). |
| GTV(3) | Storage capacity (1000 bbls.) for gasoline tank vehicles of type ITC(I). |
| IAQ | Dummy variable used in calling Subroutine OUTFI. |
| ICODE | Dummy variable used in calling Subroutine OUTFI. |
| IN | The I-th column of Table (I,J) from which an interpolated value is to be returned from Subroutine FIND. |
| INC | The incremental value used to determine the I-th vector of Table (I,J) when calling Subroutine FIND. |
| INP(12) | Name and location of plant. |
| IT(50) | Input value denoting the type of the I-th uncontrolled tanks. |
| ITC(50) | Input value denoting the types of controls on the tank type IT(I). |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| ITYP | Input value denoting the type of catalytic cracker. |
| KODE | Input value to determine when to bypass Subroutine OUTFI and/or the printout of plant data. |
| LIM | The I-th number of values in Table (I,J). |
| LL | An input variable denoting the last data card for a plant and/or the last data card for all plants. |
| LOC | National location code. |
| MAX | The J-th number of values in Table (I,J). |
| NCO | The card number for plant data. |
| NE | The number of emissions from the source. |
| NFL | The number of data fields on the card being read in. |
| NIT(50) | Variable denoting the number of tanks of input type I. |
| NPLT | The number of the plant being processed in sequential order. |
| NS | The numerical value assigned to this source. |
| OST(3) | Storage capacity (1000 bbls.) for crude oil storage tanks of type ITC(I). |
| PCT | The percentile of crude oil throughout. |
| PCT1 | Ratio of gasoline tank vehicle without vapor recovery and splash fill. |
| PCT2 | Ratio of gasoline tank vehicle without vapor recovery and submerged fill. |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| RSAC | National location code. |
| S | The amount of sulfur which could be recovered. |
| SULFA | Factor to determine the amount of sulfur that could be recovered. |
| SUM1 | The sum of the investment costs from all pollutants and all plants. |
| SUM2 | The sum of the annual operating costs from all pollutants and all plants. |
| SUR | The amount of sulfur recovered (tons/day). |
| SZ(50) | Size of storage tank of type IT(I) in thousands of barrels. |
| TABLE(2,6) | Input table giving costs ($1000) for installing a floating roof in tank having J-th capacity (1000 bbls.). |
| TEMP1 | Equated to SZ(I) in loop in order to return costs from Subroutine FIND. |
| TGTV1 | Turnover rate for gasoline tank vehicle without vapor recovery and splash fill. |
| TGTV2 | Turnover rate for gasoline tank vehicle without vapor recovery and submerged fill. |
| TOR | The annual gasoline turnover rate for storage tanks in a given plant |
| TOTCAP | Crude oil capacity of refinery (1000 b/cd) |
| WLC | Controlled hydrocarbon emissions (tons/yr.) due to working losses. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| WLGS | Hydrocarbon emissions (tons/yr.) due to working losses from gasoline storage tanks. |
| WLGT | Hydrocarbon emissions (tons/yr.) due to working losses from gasoline tank vehicles. |

## V. LISTING OF THE COMPUTER PROGRAM FOR PETROLEUM REFINING

```
C      PROGRAM REFINE
C         THIS PROGRAM COMPUTES EMISSIONS AND CONTROL COSTS FOR
C            OIL REFINERIES. THE EMISSIONS ARE:
C                 EM1(I) -PARTICULATES
C                 EM2(I) -SULFUR OXIDES
C                 EM3(I) -HYDROCARBONS
C                 EM4(I) -CARBON MONOXIDES
      INTEGER RSAC
      INTEGER COB
      DIMENSION INP(12),IT(50),ITC(50),SZ(50),GTV(3) ,TABLE(2,6),CO1(2),
     2CO2(2),CO3(2),CO4(2),ANS(2),OST(3),EM1(2),EM2(2),EM3(2),EM4(2),
     3COST(2),EMIS(4,2),NIT(50) ,GST(3)
      COST(1) = 0.
      COST(2) = 0.
      ICODE = 0
      IAO = 0
      NPLT = 0
      NE = 4
      SUM1 = 0.
      SUM2 = 0.
      DO 2 I = 1,4
      EMIS(I,1) = 0.
 2    EMIS(I,2) = 0.
      PRINT 750
      PRINT 751
C         READ IN KODE TO DETERMINE THE FOLLOWING:
C          KODE VALUE  PLANT DATA  CALL OUTFI
C          ---------  -----------  ----------
C               0          YES           NO
C               1          YES           YES
C               2          NO            YES
C               3          NO            NO
      READ 610, KODE
C         READ IN TABLE OF COST($1000) VERSUS TANK CAPACITY (1000 BBL.)
C           IN ORDER TO DETERMINE COST TO INSTALL FLOATING ROOF.
      READ 620, FA, FB, FC, FD, FE, FF, FG, FH
      READ 600,  (TABLE(1,J), TABLE(2,J), J = 1,6)
 5    CONTINUE
      LL = 0
      DO 6 I = 1,3
      GTV(I) = 0.
      GST(I) = 0.
 6    OST(I) = 0.
 10   CONTINUE
      READ 630, NCO,NS, RSAC,TOTCAP,DAY1,DAY2,(INP(I),I = 1,12)
      READ 640, ITYP,COB,SULFA,CAT,SUR
C         ITYP DENOTES THE TYPE OF CAT CRACKER AS FOLLOWSO
C           0 - NORMAL PROCESS  ONTROL W.O. ELECTROSTATIC PERCIPITATOR.
C           1 - NORMAL PROCESS  ONTROL WITH ELECTROSTATIC PERCIPITATOR.
C           2 - THERMOFOR CATALYST UNIT.
C           3 - HOUDRIFLOW CATALYST UNIT.
      NPLT = NPLT +1
      DO 11 J = 1,2
      EM1(J) = 0.
      EM2(J) = 0.
      EM3(J) = 0.
      EM4(J) = 0.
      CO1(J)=0.
      CO2(J)=0.
      CO3(J)=0.
      CO4(J) = 0.
 11   CONTINUE
 12   CONTINUE
      READ 650,NCO,NFL,LOC,( IT(I),ITC(I),NIT(I),SZ(I)          ,I=1,3),LL
C       LOC IS THE NATIONAL LOCATION CODE AND SHOULD BE THE SAME AS
C         RSAC IN READ 630.
C       IT(I) DENOTES THE INPUT TYPE WHERE "1" IS FOR UNCONTROLLED
C         CRUDE OIL TANKS AND "2" IS FOR UNCONTROLLED GAS. TANKS, AND
C         3 IS FOR GASOLINE TANK VEHICLES.
C       ITC(I) INDICATES THE TYPE OF CONTROLS AS FOLLOWS0
C         1 - FIXED ROOF TANK; IF GASOLINE W.O. VAPOR RECOVERY, SPLASH
C         FILLED.
C         2 FOR CONSERVATION TANKS AND W.O. VAPOR RECOVERY IF GASOLINE.
C         3 FOR FIXED ROOF W.O. VAPOR RECOVERY, SUMERGE FILLED.
C       NIT(I) DENOTES THE NUMBER OF TANKS OF INPUT TYPE I.
C       SZ(I) DENOTES THE SIZE OF THE UNCONTROLLED TANK OF TYPE IT.
C       GTV(I) = TOTAL STORAGE FOR ALL GASOLINE TANK VEHICLES, 1000 BBL.
C       OST(I) = TOTAL STORAGE FOR ALL CRUDE OIL TANKS, 1000 BBL.
C       GST(I) = TOTAL STORAGE FOR ALL GASOLINE STORAGE TANKS.
C       *****
C       COMPUTE THE TURNOVER RATE, TOR, FOR GASOLINE STORAGE TANKS.
      TOR = 365.0 /DAY2
      DO 100 I = 1,NFL
      TEMP1 = SZ(I)
      LIM = 2
      MAX = 6
      IN = 2
      INC = 1
      COUNT = NIT(I)
      IF(IT(I)-2)20,60,96
C      THE FOLLOWING COMPUTATIONS ARE FOR CRUDE OIL STORAGE TANKS.
 20   IF(ITC(I)-2)30,40,50
C        FIXED ROOF TANK
 30   OST(1) = OST(1) + SZ(I) * COUNT
      CALL FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
      CO3(1) =   ANS(2) + CO3(1)
      GO TO 100
C        CONSERVATION TANK
 40   OST(2) = OST(2) + SZ(I) * COUNT
      GO TO 100
C        *****
 50   PRINT 660
      GO TO 100
C      THE FOLLOWING COMPUTATIONS ARE FOR GASOLINE STORAGE TANKS.
 60   IF(ITC(I)-2)70,80,90
C        FIXED ROOF, W O. VAPOR RECOVERY, SPLASH FILL.
 70   GST(1) = GST(1) + SZ(I) * COUNT
      CALL FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
      CO3(1) =   ANS(2) + CO3(1)
      GO TO 100
C        CONSERVATION, W.O. VAPOR RECOVVERY.
 80   GST(2) = GST(2) + SZ(I) * COUNT
```

```
      GO TO 100
C        FIXED ROOF, W O. VAPOR RECOVERY SUBMERGE FILL
 90   GST(3) = GST(3) + SZ(I) * COUNT
      CALL FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
      CO3(1) =    ANS(2) + CO3(1)
C        *****
      GO TO 100
C      THE FOLLOWING COMPUTATIONS ARE FOR GASOLINE TANK VEHICLES.
 96   IF(ITC(I)-2)97,98,50
C        W/VAPOR RECOVERY, SPLASH FILL
 97   GTV(1) = GTV(1) + SZ(I) * COUNT
      GO TO 100
C        W.O  VAPOR RECOVERY, SUBMERGE FILL
 98   GTV(2) = GTV(2) + SZ(I) * COUNT
 100  CONTINUE
      IF(LL-8)12,110,110
 110  CONTINUE
C        COMPUTE THE ANNUAL THROUGHPUT OF GASOLINE (1000BBL.).
      GASV = TOR * (GST(1) + GST(2) + GST(3))
C        COMPUTE THE RATIO OF GASOLINE TANK VEHICLES  WITH SPLASH
C          FILL (PCT1), AND THE RATIO WITH SUBMERGE FILL (PCT2).
      PCT1 = GTV(1) / (GTV(1) + GTV(2))
      PCT2 = GTV(2) / (GTV(1) + GTV(2))
C        COMPUTE THE TURNOVER FOR GASOLINE TANK VEHICLES.
      TGTV1 = (GASV/GTV(1)) * PCT1
      TGTV2 = (GASV/GTV(2)) * PCT2
C        COMPUTE BREATHING LOSSES, TONS/YR. FOR GASOLINE STORAGE TANKS.
      BLGS = FA * (GST(1) + GST(3)) + FD * GST(2)
C        COMPUTE BREATHING LOSSES, TONS/YR. FOR CRUDE OIL STORAGE TANKS.
      BLCO = OST(1) * FG + OST(2) * FH
C        COMPUTE THE CONTROLLED EMISSIONS DUE TO BREATHING LOSSES.
      BLC =0.87 * (GST(1) +GST(2) + GST(3) + OST(1) + OST(2))
C        BREATHING LOSSES FROM GASOLINE TANK VEHICLES IS ZERO.
C        *****
C        COMPUTE WORKING LOSSES, TONS/YEAR FOR GASOLINE STORAGE
C          TANKS AND GASOLINE TANK VEHICLES.
      WLGS = (FB * GST(1) + FE * GST(3)) * TOR
      WLGT=FC*GTV(1)*TGTV1 + FF*GTV(2)*TGTV2
C        COMPUTE THE CONTROLLED EMISSIONS DUE TO WORKING LOSSES.
      WLC=0.152*TOR*(GST(1)+GST(2))+0.102*(GTV(1)*TGTV1+GTV(2)*TGTV2)
C        THERE ARE NO WORKING LOSSES FROM CRUDE OIL STORAGE TANKS.
C        *****
C        COMPUTE TOTAL HYDROCARBON EMISSIONS FROM ALL STORAGE TANKS AND
C          TANK VEHICLES IN 1000 TONS/YEAR.
      EM3(1) = (BLGS + BLCO + WLGS + WLGT)/1000.0
      EM3(2) = EM3(2) + (BLC + WLC)/1000.
C        THIS ENDS THE COMPUTATIONS OF HYDROCARBONS FROM STORAGE FACILI.
C        * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C        COMPUTE THE CRUDE OIL TURNOVER RATE , COT.
      COT = 365.0 / DAY1
C        COMPUTE THE CRUDE OIL TROOUGHPUT - COIL.   (1000 BBL.)
      COIL =(OST(1) + OST(2) ) * COT
C        COMPUTE THE SULFUR WHICH COULD BE RECOVERED - S.
      S = (COIL*.000145*SULFA)/1000.
      EM2(1) =((50.0 * COIL/100.) - SUR  *360.)/1000.
      EM2(2) =(530.0 * S )/1000.
      IF(EM2(1))120,122,122
 120  EM2(1) = 0.
 122  CONTINUE
```

```
C
C        COMPUTE INVESTMENT COST USING LEAST SQUARE CURVE FIT TO SULFUR
C          PLANT CAPACITY,T/D, VERSUS COST, $1000.
C        THERE ARE NO ANNUAL CONTROL COSTS FOR CONTROL OF SO BECAUSE THE
C          OPERATION IS A BREAKEVEN OR PROFITABLE OPERATION.
C
C
      C02(1) = 15.3956 + 17.2803 *S - 0.2231* S**2 + 0.0005 * S**3
C        EMISSIONS FROM CAT CRACKER ARE PARTICULATES, HYDROCARBONS,
C          AND CARBON MONOXIDES.
C        COST OF PARTICULATE CONTROL 0
C
      C01(1)=(1950.* CAT + 110000 )/1000.
      C01(2)=( 450.* CAT + 15000. )/1000.
C        COMPUTE EMISSIONS FROM CAT CRACKER. (1000TONS)
C
C        ANNUAL CAPACITY OF THE CAT CRACKING IS 360 X B/SD, (1000 B).
      CCAT = CAT * 360.0
C        COMPUTE UNCONTROLLED EMISSIONS OF PARTICULATES, HYDROCARBONS,
C          AND CARBON MONOXIDES FROM CAT CRACKING.
C        CO BOILERS CONTROL HYDROCARBONS AND CARBON MONOXIDE 100%.
C        ELECTROSTATIC PERCIPITATORS CONTROL PARTICULATES 90%.
C
      IF(ITYP-1)130,140,150
 130  CONTINUE
C        CAT CRACKER WITHOUT ELECTROSTATIC PERCIPITATOR.
      EM1(1) = EM1(1) + (6.25 * CCAT)/2000000.0
      EM1(2) = 0.10 * EM1(1)
      IF(COB-1)132,160,132
 132  EM4(1) = EM4(1) + (5.6 * CCAT)/1000.0
      EM3(1) = (32.4 * CAT)/1000.0   + EM3(1)
      C04(1) = CAT * 5.1875 + 257.5 + C04(1)
      GO TO 160
 140  CONTINUE
      EM1(1) = 0.10 * (6.25 * CCAT)/2000000.
      EM1(2) = 0.10 * (6.25 * CCAT)/2000000.
      C01(1) = 0.
      C01(2) = 0.
      IF(COB-1)142,160,142
 142  EM4(1) = EM4(1) + (5.6 * CCAT)/1000.0
      EM3(1) = (32.4 * CAT)/1000.0  + EM3(1)
      C04(1) = CAT * 5.1875 + 257.5 + C04(1)
      GO TO 160
 150  CONTINUE
C        CAT CRACKER WITH THERMOFOR OR HOUDRIFLOW UNIT.
      EM1(1) = (0.52 * CCAT)/2.0
      EM1(2) = 0.10 * EM1(1)
      IF(ITYP-3)152,160,160
 152  CONTINUE
      IF(COB - 1)154,160,154
 154  CONTINUE
      EM3(1) = (10.3* CCAT)/1000.0    + EM3(1)
      EM4(1) = (1.2 * CCAT)/1000.0
      C04(1) = CAT * 5.1875 + 257.5 + C04(1)
 160  CONTINUE
      COST(1) = COST(1) + C01(1) + C02(1) + C03(1) + C04(1)
      COST(2) = COST(2) + C01(2) + C02(2) + C03(2) + C04(2)
      EMIS(1,1) = EMIS(1,1) + EM1(1)
      EMIS(1,2) = EMIS(1,2) + EM1(2)
      EMIS(2,1) = EMIS(2,1) + EM2(1)
      EMIS(2,2) = EMIS(2,2) + EM2(2)
      EMIS(3,1) = EMIS(3,1) + EM3(1)
      EMIS(3,2) = EMIS(3,2) + EM3(2)
      EMIS(4,1) = EMIS(4,1) + EM4(1)
      EMIS(4,2) = EMIS(4,2) + EM4(2)
      SUM1 =  SUM1 + COST(1)
      SUM2 =  SUM2 + COST(2)
      IF(KODE-1)200,210,220
 200  CONTINUE
C        PRINT PLANT DATA.
      PRINT 760,NPLT,(EM1(I),EM2(I),EM3(I),EM4(I),I=1,2),COST(1),COST(2)
      GO TO 5
 210  CONTINUE
      PRINT 760,NPLT,(EM1(I),EM2(I),EM3(I),EM4(I),I=1,2),COST(1),COST(2)
      IF(KODE - 3)220,250,250
 220  CONTINUE
      CALL OUTF1 (RSAC,ICODE,IAQ,NS,INP,COST,NE,1,EM1,2,EM2,3,EM3,4,EM4)
 250  CONTINUE
      IF(LL-8)5,5,300
 300  CONTINUE
C        PRINT GRAND TOTALS AND END PROGRAM.
C
      PRINT 770,((EMIS(I,J),I=1,4),J=1,2), SUM1, SUM2
 600  FORMAT (12F5.0)
 610  FORMAT (I5)
 620  FORMAT (8F10.4)
 630  FORMAT (I2,I3,A4,1X,F10.2, 2F5.1     ,12A4)
 640  FORMAT (10X,2I2,F6.2,2F10.3)
 650  FORMAT (I2,I3,A4,1X,3(2I2,I3,F8 2, 5X ),I2)
 660  FORMAT (37H ERROR IN INPUT DATA,IT(I) OR ITC(I).)
 750  FORMAT(47X,25HPETROLEUM REFINING PLANTS,/ 35X,50HESTIMATES OF EMIS
     2SION LEVELS AND ASSOCIATED COSTS ,//)
 751  FORMAT (119HNO.  PRESENT EMISSION LEVEL (1000 TONS/YEAR)
     2CONTROLLED EMISSION LEVEL (1000 TONS/YEAR)      INVESTMENT  ANNUAL,
     3//)
 760  FORMAT (I3,1X,8F12.2,2F10.0)
 770  FORMAT (4X,8F12.2,2F10 0)
      STOP
      END

      SUBROUTINE FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
C          THE PURPOSE OF THE SUBROUTINE IS TO DO A TABLE LOOKUP
C            FOR ANY TABLE(I,J) BASED ON THE FOLLOWING
C                I = 1,LIM
C                J = 1,MAX
C                TEMP1 IS THE PARAMETER FOR WHICH VALUES ARE FOUND
C                ANS(I) IS THE INTERPOLATED VALUE FOR TEMP1
C                IN IS THE BEGINNING OF I
C                INC IS THE INCREMENT OF I
      DIMENSION TABLE(2,6),ANS(2)
      IF (TEMP1-TABLE(1,1))5,5,6
 5    CONTINUE
      DO 4 I = IN,LIM,INC
 4    ANS(I) = TABLE(I,1)
      GO TO 60
 6    CONTINUE
      IF(TEMP1-TABLE(1,MAX))9,9,8
 8    PRINT 100
```

```
100   FORMAT(48H PLANT SIZE IS LARGER THAN MAXIMUM SIZE IN TABLE,//)
      DO 7 I = IN,LIM,INC
7     ANS(I) = TABLE(I,MAX)
      GO TO 60
9     CONTINUE
      DO 30 J = 1,MAX
      IF (TEMP1-TABLE(1,J))10,20,30
   10 RATIO = (TEMP1-TABLE(1,J-1)) /(TABLE(1,J) - TABLE(1,J-1))
      JJ = J
      GO TO 40
   20 RATIO = 1.0
      JJ = J
      GO TO 40
   30 CONTINUE
   40 DO 50 I = IN,LIM,INC
   50 ANS(I) = RATIO *(TABLE(I,JJ)-TABLE(I,JJ-1)) + TABLE(I,JJ-1)
60    CONTINUE
      RETURN
      END
```

```
 INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS:


   0
   8 5        0.2420     0.1720     0.8700     0.1520     0.1020     1.6300     0.9000
   0   14   25   20   50   32   75   45  100   68  200  160
```

## APPENDIX N

## Computer Program for Phosphate Fertilizer

# Appendix N

## Computer Program for Phosphate Fertilizer

### I. INTRODUCTION

This program calculates control costs and emissions (1967 and the year of final control) on a plant by plant basis for the phosphate fertilizer industry. The eight production processes and the associated process codes as used in this program are: normal superphosphate-1; diammonium phosphate-2; triple superphosphate-3; wet process orthophosphoric acid-4; furnace orthophosphoric acid-5; poly vacuum phosphoric acid-6; poly submerged phosphoric acid-7; poly furnace phosphoric acid-8. Figure N-1 shows a flow diagram of the computer program logic.

The remainder of this appendix contains four sections. Section II lists the specific assumptions on which the program is based; Section III describes program operations and capabilities in detail; Section IV is a glossary of all FORTRAN names used in the program; and Section V is a complete listing of the program followed by the parameters used in producing the economic analysis figures.

### II. ASSUMPTIONS

The assumptions made in this program are:

a) Costs and emissions are adequately calculated from table look-up procedures with linear interpolation when required;

b) Beyond a certain plant size or indicated process size, all process stream emissions and control costs can be accurately represented by successively halving the process size and doubling the number of "process streams";

c) Only fluoride emissions need further control in this industry.

The figures presented in this report are based on values of parameters given in the listing at the end of Section V. (It should be noted that the emission factors for processes 5, 7, 8, and control costs for processes 5, 6, 7, and 8 are zero because fluoride emissions require no further controls to meet the assumed standards.)

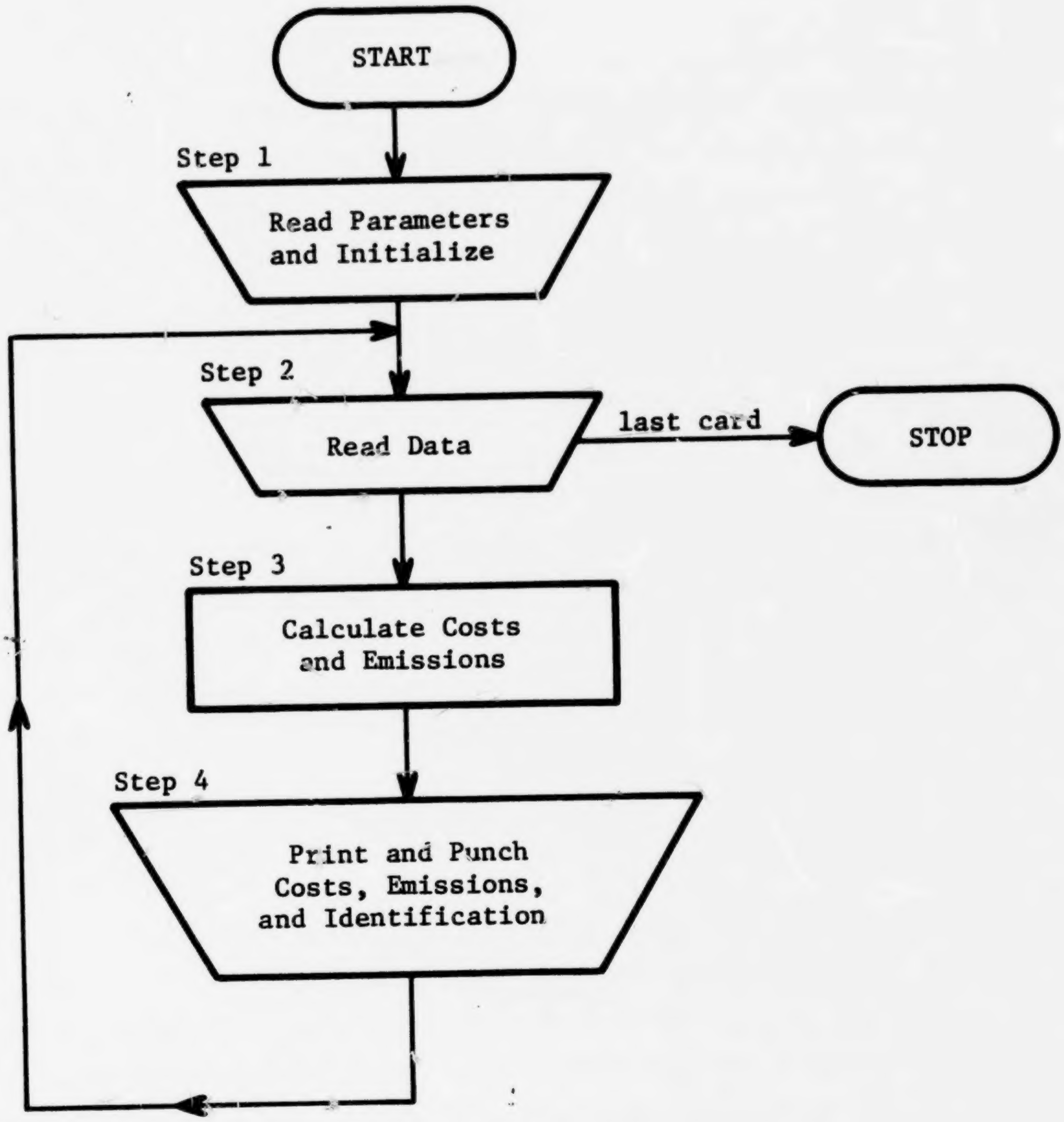

START
Step 1
Read Parameters and Initialize
Step 2
Read Data
last card
STOP
Step 3
Calculate Costs and Emissions
Step 4
Print and Punch Costs, Emissions, and Identification

Fig. N-1. - Flow Chart for the Phosphate Fertilizer Computer Program.

## III. PROGRAM OPERATIONS

The step numbers refer to steps in the flow chart of Figure N-1.

Step 1.

Parameters are read and variables are initialized. For parameter details see Table N-1 and the listing of parameters at the end of Section V.

Step 2.

Plant data for one plant are read in the standard plant data format. A code of IAUX=0 indicates data for the whole plant and with a reading of card type 1 only for the plant. IAUX=1 indicates detailed plant data are included and require reading of one or more type 2 data cards (Table N-2).

Step 3.

For each plant or process within the plant, a table look-up is performed to find costs. If a capacity value falls between table values, a linear interpolation is performed. If a capacity value is outside the range of the table, the capacity value is successively halved until it does fall within the table, and the resulting costs and emissions are multiplied by the appropriate power of 2. Investment and annual costs are accumulated for the plant in C1(1) and C1(2), respectively. Emissions for 1967 and after controls are initiated, are calculated by using emission factors and accumulated in E1(1) and E1(2), respectively.

Step 4.

When all processes for a plant have been finished, costs and emissions are printed and, using subroutine OUTFI, punched. Control is returned to Step 2 for subsequent data. If there are no additional data the program terminates.

## TABLE N-1. - LIST OF PARAMETERS FOR PROGRAM FERT

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| C(3,10,8) | Ten-capacity, eight-process cost parameters. Entry 1 is capacity for the group, entry 2 is investment cost, and entry 3 is annual cost. Each group of three entries is repeated for ten capacities for each of the eight processes. See the parameters listed at the end of Section V for the values actually used in the program. | 1-24 | 10F8.0 |
| CFACT(8) | Factors for each of the eight processes which convert total capacity for the process to equivalent $P_2O_5$ capacity. Values used in this report are shown at the end of Section V. | 25 | 10F8.0 |
| EFACT(2,8) | Fluoride emission factors for each of the eight processes (1) before, and (2) after, applying controls with costs contained in array C. Values used in this report are shown at the end of Section V. | 26-27 | 10F8.0 |

TABLE N-2. - INPUT DATA DESCRIPTION FOR PROGRAM FERT

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards type 1 & 2 | | |
| | Blank. | 1 | 1X |
| IAUX | Variable to specify presence or absence of detailed data. | 3 | I1 |
| ICODE | Card type code. | 2 | I1 |
| RSAC1,RSAC2 | Location codes. | 6-9,10 | A4,A1 |
| SCODE | Source identification code. | 4-5 | F2.0 |
| | Card type 1 | | |
| | Blank. | 27-30 | 4X |
| INPUT(12) | Plant identification data. | 31-78 | 12A4 |
| IP | Process type (used for nondetailed plant data). | 23-26 | I4 |
| NPROC | Number of unit process described on card(s) type 2. | 11-12 | I2 |
| TOTCAP | Total plant capacity | 13-22 | F10.0 |
| | Card type 2 | | |
| | Blank . | 26-30,<br>46-50,<br>66-70 | 5X |
| DATA(3,10) | Input storage for detailed plant data. Ten possible different unit processes. Row 1 contains 1967 control level of the process, Row 2 contains number of unit processes of this type, Row 3 contains capacity of this process type. | Row 1:<br>13-15,<br>33-35,<br>53-55 | F3.0 |
| | | Row 2:<br>16-17,<br>36-37,<br>56-57 | F2.0 |
| | | Row 3:<br>18-25,<br>38-45,<br>58-65 | F8.0 |
| ITYPE(10) | Process type identification for detailed plant data, corresponding to array DATA. | 11-12,<br>31-32,<br>51-52 | I2 |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| AQCR | Variable to transfer metropolitan area number to subroutine OUTFI. Currently a dummy variable. |
| C(3,10,8) | Array of costs and corresponding sizes (see listing at end of Section V). |
| C1(2) | Array for storing plant costs. |
| CFACT(8) | Array of conversion factors from nominal capacity to equivalent $P_2O_5$ capacity. |
| DATA(3,10) | Array for storing input data for detailed plant data situation. |
| DEL | Interpolation factor between two points in C. |
| DFACT | Number of units of a process. |
| E1(2) | Array for storing plant emissions. |
| EFACT(8) | Array for storing plant emissions. |
| I,J,K | Dummy indexing variables. |
| IAUX | Variable specifying whether detailed data is present. |
| ICODE | Code identifying card types 1 and 2. |
| INPUT(12) | Array storing plant name and location. |
| IP | Unit process type. |
| ITYPE(10) | Storage of unit process type for detailed data input. |
| MPROC | Input counter for type 2 cards. |
| NPROC | Number of unit processes. |
| OUTFI | Standard output routine. |
| RSAC1, RSAC2 | Region, State, Area, County code. |
| SCODE | Source code. |
| TOTCAP | Total plant capacity. |

## V. LISTING OF THE COMPUTER PROGRAM FOR PHOSPHATE FERTILIZER

```
C     PROGRAM FERT
C     THIS PROGRAM CALCULATES CONTROL COSTS AND EMISSIONS FOR THE PHOS-
C     PHATE FERTILIZER INDUSTRY.
C
C     PROCESS TYPE CODES AREO 1-NSP, 2-DAP, 3-TSP, 4-WET ORTHO ACIB, 5-
C     FURNACE ORTHO ACID, 6-POLY VACUUM ACID, 7-POLY SUBMERGED ACIB, 8-
C     POLY FURNACE ACID.
C
C     CONTROL COSTS FOR 1, 2, 3, + 4 ONLY.  EMISSIONS FOR 1, 2, 3, 4, + 6
C     ONLY.  OTHER PROCESSES ARE FOR FUTURE USE IF NEEDED.
C
      DIMENSION INPUT(12), C(3,10,8), EFACT(2,8), C1(2), E1(2), CFACT(8)
C
C     INITIALIZE
C
      DO 20 I=1,8
      CFACT(I)=0.
      DO 10 J=1,2
      EFACT(J,I)=0.
      C1(J)=0.
      E1(J)=0.
   10 CONTINUE
      DO 20 J=1,10
      DO 20 K=1,3
      C(K,J,I)=0.
   20 CONTINUE
      DO 30 I=1,12
      INPUT(I)=0
   30 CONTINUE
C
C     READ IN COSTS (C), CONVERSION FACTORS (CFACT), AND EMISSION FACTORS
C     (EFACT)
C
      READ 5000, C
 5000 FORMAT(10F8.0)
      READ 5000, CFACT
      READ 5000, EFACT
C
C     READ DATA.
C
   40 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      F=0.
      READ 5005, ICODE, IAUX, SCODE, RSAC1, RSAC2, NPROC, TOTCAP, IP,
     1 INPUT
 5005 FORMAT(1X,2I1,F2.0,A4,A1,I2,F10.0,I4,4X,12A4)
C
C     CHECK CODES
C
      IF (ICODE-1) 2000,50,1000
   50 IF (SCODE-11.) 1020,60,1020
   60 IF (IAUX) 1010,70,81
   70 IF (IP) 1030,1030,80                                                 11  0490
   80 IF (IP-8) 90,90,1030                                                 11  0500
C
C   READ DATA CARD(S) TYPE 2
C
      MPROC=NPROC/3
      IF (MPROC) 84,84,82
   82 DO 83 I=1,MPROC
      J=(I-1)*3+1
      K=J+2
      READ 5006, (IUNIT(L),DATA(M,L),M=1,3),L=J,K)
 5006 FORMAT(10X,I2,F2.0,F3.0,F8.0,5X,I2,F2.0,F3.0,F8.0,5X,I2,F2.0,F3.0,
     1 F8.0)
   83 CONTINUE
   84 MPROC=MPROC*3+1
      IF (MPROC-NPROC) 85,85,86
   85 READ 5006, (IUNIT(L),(DATA(M,L),M=1,3),L=MPROC,NPROC)
   86 MPROC=0
      GO TO 200
C                                                                          11  0510
C   CALCULATE TONS/DAY OF 100( P205, COSTS, AND EMISSIONS                  11  0520
C                                                                          11  0530
   90 DFACT=1.                                                             11  0571
   95 CAP=TOTCAP*CFACT(IP)
      DO 120 I=2,10
      IF (CAP-C(1,I,IP)) 100,110,120                                       11  0600
  100 DEL=(C(1,I,IP)-CAP)/(C(1,I,IP)-C(1,I-1,IP))                          11  0610
      C1(1)=(C(2,I-1,IP)-C(2,I,IP))*DEL+C(2,I,IP)                          11  0620
      C1(2)=(C(3,I-1,IP)-C(3,I,IP))*DEL+C(3,I,IP)                          11  0630
      GO TO 130                                                            11  0640
  110 C1(1)=C(2,I,IP)*DFACT
      C1(2)=C(3,I,IP)*DFACT
      GO TO 130                                                            11  0670
  120 CONTINUE                                                             11  0680
      CAP=CAP/2.                                                           11  0681
      DFACT=DFACT*2.                                                       11  0682
      GO TO 95                                                             11  0683
  130 E1(1)=CAP*EFACT(1,IP)*DFACT*(1.0-F)
      E1(2)=CAP*EFACT(2,IP)*DFACT                                          11  0700
      C1(1)=C1(1)*DFACT                                                    11  0701
      C1(2)=C1(2)*DFACT                                                    11  0702
      IF (NPROC) 140,140,200
  140 PRINT 5555, RSAC1, RSAC2, CAP, C1, E1
 5555 FORMAT(1X,A4,A1,6F15.2)                                              11  0720
      CALL OUTFI(RSAC1,RSAC2,AQCR,11,INPUT,C1,1,5,E1)
      GO TO 40                                                             11  0730
C
C   INITIALIZE FOR IDEAL CASE
C
  200 MPROC=MPROC+1
      IF (MPROC-NPROC) 210,210,140
  210 IP=IUNIT(MPROC)
      DFACT=DATA(2,MPROC)
      F=DATA(1,MPROC)
      TOTCAP=DATA(3,MPROC)
      GO TO 95
C                                                                          11  0740
C   ERROR ROUTINES                                                         11  0750
```

```
C
 1000 PRINT 5010, RSAC1, RSAC2
 5010 FORMAT(20H CARD CODE ERROR IN ,A4,A1)
      GO TO 40
 1010 PRINT 5015, IAUX, RSAC1, RSAC2
 5015 FORMAT(22H AUXILIARY CODE ERROR,,I2,4H IN ,A4,A1)
      GO TO 40
 1020 PRINT 5020, SCODE, RSAC1, RSAC2
 5020 FORMAT(19H SOURCE CODE ERROR,,F4.0,4H IN ,A4,A1)
      GO TO 40
 1030 PRINT 5025, IP, RSAC1, RSAC2
 5025 FORMAT(17H TYPE CODE ERROR,,I5,4H IN ,A4,A1)
      GO TO 40
C
C   END ROUTINE
C
 2000 PRINT 5030
 5030 FORMAT(12H-GOOD FINISH)
      STOP
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

```
     0.        0.        0.       12.       55.       18.       24.       80.       22.       48.
   120.       28.       96.      170.       41.      192.      245.       68.      384.      350.
   110.        1.        0.        0.        2.        0.        0.        3.        0.        0.
     0.        0.        0.       50.       18.        6.      100.       28.       10.      200.
    42.       15.      400.       64.       25.      800.       94.       45.     1000.      165.
    64.     2000.      340.      130.     4000       680.      250.     6000.     1000.      375.
     0.        0.        0.       50.      180.       52.      100.      270.       80.      200.
   400.      120       400.      600.      180       800.      900.      275.     1800.     1200.
   340.     2000.     2400.      660.     4000.     4800.     1400.    10000.    12000.     2000.
     0.        0.        0.       25.       41.       12.       50.       62.       20.      100.
    90.       30.      200       140.       50.      400.      200.       78.      600.      250.
   105.      800.      340.      140.     1000       420.      175.     2000.      860.      350.
     0.        0.        0.    10000.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.    10000.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.    10000.        0.        0.        0.        0.        0.        0.
     0.        0         0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.    10000.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0         0.        0.        0.        0.        0.
     0.        0.        0.        0.        0         0.        0.        0.        0.        0.
 .66667     1.53      1.53      3.30        1.      3.30        1.        1.
 .03454   .01179    .01148    .00144    .01560    .00156    .03120    .00312        0.        0.
 .00390   .00390        0.        0.        0.        0.
```

# APPENDIX O

## Primary Nonferrous Metallurgy: Aluminum

# Appendix O

## Primary Nonferrous Metallurgy: Aluminum

### I. INTRODUCTION

The primary aluminum industry produces metallic aluminum from ores. The emissions for which control costs and emissions are calculated by this program are fluorides, both particulate and gaseous, and nonfluoride particulates. Costs are calculated using a table lookup procedure. The program is designed to use detailed data techniques where all relevant data are available.

The remainder of this Appendix is organized as follows: Section II lists in detail the assumptions on which the program is based; Section III describes the actual program operations; Section IV is a glossary of the FORTRAN names used in the program; and Section V contains listing of the program, followed by the parameters used thus far.

### II. MAJOR ASSUMPTIONS

The major assumptions upon which the program calculations are based are:

a) The emissions to be controlled are nonfluoride particulates and particulate and gaseous fluorides.

b) The same required control efficiencies apply for fluoride and nonfluoride particulates.

c) Both investment and annualized costs are a linear function of capacity.

d) Some plants may have met the applicable standards in 1967.

e) There are three different processes of aluminum production, each with its own independent associated emission factors and control costs.

The parameters used for the costs and emissions calculations in this report are described in Table O-1 and shown explicitly at the end of Section V. Process types included, with the identification number, are:

TABLE O-1. - LIST OF PARAMETERS

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| INVA(3) | Coefficients "a" for investment cost equation. | 1-36 | 3F12.0 |
| INVB(3) | Coefficeints "b" for investment cost equation. | 37-72 | 3F12.0 |
| | Card 2 | | |
| ANNA(3) | Coefficients "a" for annualized cost equation. | 1-36 | 3F12.0 |
| ANNB(3) | Coefficents "b" for annualized cost equation. | 37-72 | 3F12.0 |
| | Card 3 | | |
| PART(2,3) | Uncontrolled and controlled nonfluoride particulate emission factors. | 1-72 | 6F12.0 |
| | Card 4 | | |
| FLUOR(2,3) | Uncontrolled and controlled fluoride emission factors. | 1-72 | 6F12.0 |

prebaked cells -1; vertical spike soderberg cells-2; horizontal spike soderberg cells-3.

## III. PROGRAM LOGIC

Step numbers refer to the flow chart in Figure 0-1.

Step 1: Storage is initialized and the parameters are read in (see Table 0-1).

Step 2: Costs and emissions accumulation storage are zeroed. Data for one plant are read in (see Table 0-2).

Step 3: Costs and emissions are calculated for each unit process within the plant. Costs for each unit process are calculated as a linear function of the form cost = ax+b, where a and b are parameters and x is the unit process capacity. The "a" and "b" parameters are stored in INVA and INVB for investment costs, and ANNA and ANNB for annualized costs. If CON has a value of 99 for any unit process, no costs are assigned.

Emissions are calculated as linear functions of capacity using parameters in PART and FLUOR as emission factors. If the value of CON is 99 for a particular unit process, it is assumed to be adequately controlled, and controlled and 1967 emissions are the same.

Investment costs are accumulated for a plant in C1(1) annualized costs in C1(2), nonfluoride particulate emissions in E1(1) for 1967, and E1(2) for final and total fluoride emissions in E2(1) for 1967 and E2(2) for final.

Step 4: Standard output, consiting of plant name and location, RSAC codes, costs, and emissions, are printed. Standard output is provided by Subroutine OUTFI and control is transferred to Step 2. The program halts when the last card is read.

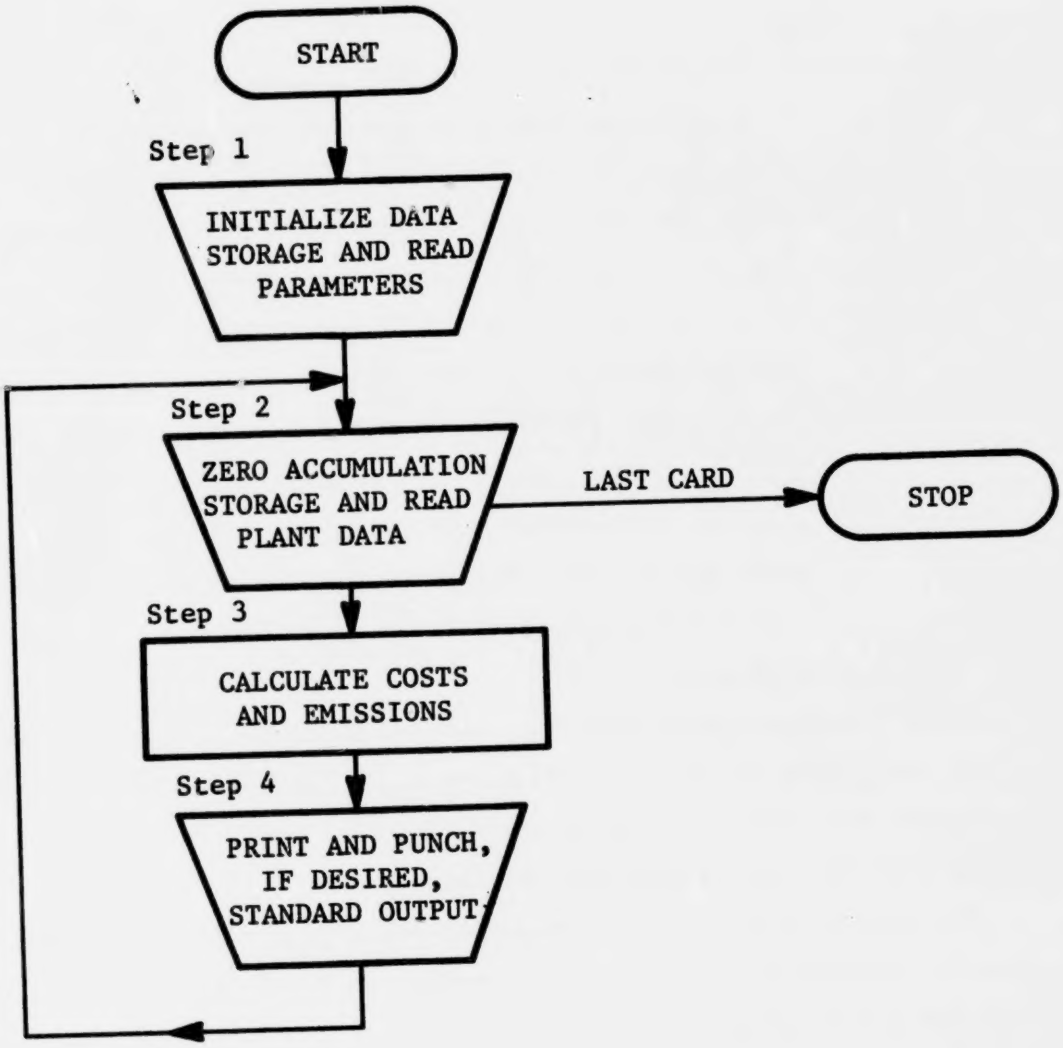

START
Step 1
INITIALIZE DATA STORAGE AND READ PARAMETERS
Step 2
ZERO ACCUMULATION STORAGE AND READ PLANT DATA
LAST CARD
STOP
Step 3
CALCULATE COSTS AND EMISSIONS
Step 4
PRINT AND PUNCH, IF DESIRED, STANDARD OUTPUT

Fig. 0-1. Program Flow Chart for Primary Aluminum.

TABLE 0-2. - LIST OF PLANT INPUT DATA

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card Type 1 | | |
| ICARD | Card type identification. | 1-2 | I2 |
| IAUX | Input type identification (not required). | 3 | I1 |
| ICODE | Industry code (31 for primary nonferrous: aluminum). | 4-5 | I2 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| NPROC | Number of individual unit processes on card type 2. | 11-12 | I2 |
| TOTCAP | Total plant capacity. | 13-22 | F10.0 |
| | Blanks. | 23-30 | 8X |
| INPUT(12) | Plant name and location. | 31-78 | 12A4 |
| | Card Type 2 | | |
| ICARD | Card type identification. | 1-2 | I2 |
| IAUX | Input type identification (not required). | 3 | I1 |
| ICODE | Industry code (31 for primary nonferrous: aluminum). | 4-5 | I2 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| ITYPE(10) | Process type code. | 11-12, 31-32, 51-52 | I2 |
| ANUM(10) | Number of processes of each type. | 13-15, 33-35, 53-55 | F3.0 |
| CON(10) | Control level (1967) of each process type. | 16-17, 36-37, 56-57 | F2.0 |
| CAP(10) | Capacity of each process type. | 18-25, 38-45, 58-65 | F8.0 |
| | Blanks. | 26-30, 46-50, 66-70 | 5X |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| ANNA(3), ANNB(3) | Parameters for annualized cost equation (see Table 0-1). |
| ANUM(10) | Numbers of each unit process within plant (see Table 0-2). |
| C1(2) | Vector for accumulating plant costs. |
| CAP(10) | Capacity of each unit process with plant (see Table 0-2). |
| CON(10) | 1967 control level of each unit process within plant (see Table 0-2). |
| E1(2) | Vector for accumulating nonfluoride particulate emissions. |
| E2(2) | Vector for accumulating fluoride emissions. |
| FLUOR(2,3) | Fluoride emission factor parameters (see Table 0-1). |
| I | Indexing parameter. |
| IAUX | Input type identification (not used). |
| ICARD | Card type identification. |
| ICODE | Industry identification (31 for primary aluminum). |
| INVA(3), INVB(3) | Parameters for investment cost equation (see Table 0-1). |
| IT | Temporary storage for ITYPE. |
| ITYPE(10) | Unit process type code (see Table 0-2). |
| NPROC | Number of distinct unit process in plant. |
| PART(2,3) | Nonfluoride particulate emission factor parameters (see Table 0-1). |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |

# V. LISTING OF THE COMPUTER PROGRAM FOR PRIMARY ALUMINUM

```
C     PROGRAM ALUM
C     THIS PROGRAM CALCULATES COSTS AND EMISSIONS FOR GONTROLLING THE
C     PRIMARY ALUMINUM REFINING INDUSTRY.
C
C     THE EMISSIONS FROM THIS INDUSTRY ARE FLUORIDE ANB NON-FLUORIBE
C     PARTICULATES AND GASEOUS FLUORIDES.  FOR OUTPUT +DENTIFICATION PUR-
C     POSES, NON-FLUORIDE PARTICULATES ARE IDENTIFIED AS EMISSION TYPE 1,
C     AND ALL FLUORIDES AS EMISSION TYPE 5.
C
C     COSTS AND EMISSIONS ARE LINEAR FUNCTIONS OF CAPABITY AND ARE CALCU-
C     LATED IN EQUATIONS OF THE FORM A(I)*CAPACITY+B(I), WHERE A AND B ARE
C     MATRICES CONTAINING THE APPROPRIATE CONSTANTS, AND I IS THE APPRO-
C     PRIATE PROCESS TYPE NUMBERO (1) FOR PRE-BAKED CELLS; (2) FOR VERTI-
C     CAL SPIKE SODERBURG; AND (3) FOR HORIZONTAL SPIKE SODERBURG.
C
C     THE "A" AND "B" MATRICES AREO INV FOR INVESTMENT COSTS; ANN FOR ANN-
C     UAL COSTS; PART FOR NON-FLUORIDE PARTICULATE EMISSION FACTORS; AND
C     FLUOR FOR FLUORIDE EMISSION FACTORS.
C
C     COSTS ARE STORED IN ARRAY C1; NON-FLUORIDE PARTICULATE EMISSIONS IN
C     E1(1) (1967) AND E1(2) (FINAL); FLUORIDE EMISSIONS IN E2(1) (1967)
C     AND E2(2) (FINAL).
C
      REAL INVA, INVB
      DIMENSION INVA(3), INVB(3), ANNA(3), ANNB(3), PART(2,3),
     1 FLUOR(2,3), C1(2), E1(2), E2(2), INPUT(12), ITYPE(12), ANUM(12),
     2 CON(12), CAP(12)
C
C     INITIALIZE MATRICES.
C
      DO 10 I=1,3
      INVA(I)=0.
      INVB(I)=0.
      ANNA(I)=0.
      ANNB(I)=0.
      DO 10 J=1,2
      PART(J,I)=0.
      FLUOR(J,I)=0.
   10 CONTINUE
      DO 20 I=1,12
      INPUT(I)=0
   20 CONTINUE
C
C     READ PARAMETERS.  UNITS OF COSTS ARE THOUSANDS OF DOLLARS/TON OF
C     ANNUAL CAPACITY.  EMISSION FACTORS ARE TONS/TON OF ANNUAL CAPACITY.
C
      READ 5000, PART, FLUOR, INVA, INVB, ANNA, ANNB
 5000 FORMAT(6F10.0)
      PRINT 5001, PART, FLUOR, INVA, INVB, ANNA, ANNB
 5001 FORMAT(6F12.7)
C
C     ZERO OUT COST AND EMISSION STORAGE AREAS AND REAB INPUT DATA.  CARD
C     TYPE 1 CONTAINSO CARD TYPE "ICARD" (I2), AUXILIARY CODE "IAUX" (I1),
C    SOURCE CODE "ICODE" (I2), RSAC CODE "RSAC1" (A4), RSAC SUBDIVISION
C    CODE "RSAC2" (A1), NUMBER OF UNIT PROCESSES FOR THIS PLANT "NPROC"
C    (I2), TOTAL PLANT CAPACITY "TOTCAP" (F10.0), AND PLANT IDENTIFICA-
C    TION DATA "INPUT" (8X,12A4)
C
   30 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      E2(1)=0.
      E2(2)=0.
      READ 5005, ICARD, IAUX, ICODE, RSAC1, RSAC2, NPROC, TOTCAP, INPUT
 5005 FORMAT(I2,I1,I2,A4,A1,I2,F10.0,8X,12A4)
      IF (ICARD-1) 2000,40,1000
   40 IF (ICODE-31) 1010,50,1010
C
C    READ DATA CARD TYPE 2.  THE FIRST TEN COLUMNS ARE THE SAME FIELDS AS
C    FOR CARD TYPE 1.  SUBSEQUENT FIELDS, IN THREE GROUPS (COLUMNS 11-25,
C    31-45, AND 51-65) ARE PROCESS TYPE "ITYPE" (I2), NUMBER OF THIS PRO-
C    CESS TYPE AND SIZE IN PLANT "ANUM" (F3.0), 1967 CONTROL LEVEL "CON"
C    (F2.0), PROCESS SIZE "CAP" (F8.0).  NPROC PROCESSES ARE READ FOR
C    THE PLANT.
C
   50 READ 5010, ICARD, IAUX, ICODE, RSAC1, RSAC2, (ITYPE(I), ANUM(I),
     1 CON(I), CAP(I), I=1,NPROC)
 5010 FORMAT(I2,I1,I2,A4,A1,(I2,F3.0,F2.0,F8.0,5X,I2,F3.0,F2.0,F8.0,5X,
     1 I2,F3.0,F2.0,F8.0))
      IF (ICARD-2) 1020,60,1020
   60 IF (ICODE-31) 1010,100,1010
C
C    CALCULATE COSTS AND EMISSIONS.  IF 1967 CONTROL LEVEL GE 99(, NO
C    COSTS ARE ASSIGNED, AND 1967 EMISSIONS ARE THE SAME AS FINAL EMIS-
C    IONS.
C
  100 DO 130 I=1,NPROC
      IT=ITYPE(I)
      E1(2)=E1(2)+PART(2,IT)*ANUM(I)*CAP(I)
      E2(2)=E2(2)+FLUOR(2,IT)*ANUM(I)*CAP(I)
      IF (CON(I)-99.) 110,120,120
  110 C1(1)=C1(1)+(INVA(IT)*CAP(I)+INVB(IT))*ANUM(I)
      C1(2)=C1(2)+(ANNA(IT)*CAP(I)+ANNB(IT))*ANUM(I)
      E1(1)=E1(1)+PART(1,IT)*ANUM(I)*CAP(I)
      E2(1)=E2(1)+FLUOR(1,IT)*ANUM(I)*CAP(I)
      GO TO 130
  120 E1(1)=E1(1)+PART(2,IT)*CAP(I)*ANUM(I)
      E2(1)=E2(1)+FLUOR(2,IT)*CAP(I)*ANUM(I)
  130 CONTINUE
C
C    OUTPUT RESULTS.  SEE SUBROUTINE OUTFI FOR ITS FUNCTION.
C
      PRINT 5015, RSAC1, RSAC2, INPUT, C1, E1, E2
 5015 FORMAT(1X,A4,A1,3X,12A4,6F10.2)
      CALL OUTFI(RSAC1,RSAC2,AQCR,33,INPUT,C1,2,1,E1,5,E2)
      GO TO 30
C
C    ERROR ROUTINES.
C
 1000 PRINT 5020, INPUT
 5020 FORMAT(6H CARD ,12A4,25H SHOULD HAVE BEEN TYPE 1.)
```

```
      GO TO 30
 1010 PRINT 5025, INPUT
 5025 FORMAT(31H INVALID SOURCE CODE FOR PLANT ,12A4)
      GO TO 30
 1020 PRINT 5030, INPUT
 5030 FORMAT(7H PLANT ,12A4,26H IS MISSING A CARD TYPE 2.)
      GO TO 30
C
C   END ROUTINE
C
 2000 PRINT 5035
 5035 FORMAT(12H1GOOD FINISH)
      STOP
      END
      SOURCE LIST
      SUBROUTINE OUTFI
      RETURN
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

# APPENDIX P

## Primary Nonferrous Metallurgy: Copper

# Appendix P

# Primary Nonferrous Metallurgy: Copper

## I. INTRODUCTION

The primary copper industry produces metallic copper from ores. The emission for which control costs and emissions are calculated by this program is sulfur oxide, primarily as sulfur dioxide. Costs are calculated using a table lookup procedure when detailed plant data are available. The program is designed to use model plant calculating techniques (when IAUX=2), total plan capacity techniques (when IAUX=1), or detailed data techniques (when IAUX=0).

Figure P-1 is a flow chart for the program. The remainder of this appendix is organized as follows: Section II lists the assumptions on which the program is based in detail; Section III describes the actual program operations; Section IV is a glossary of the FORTRAN names used in the program; and Section V contains a listing of the program, followed by the parameters used thus far.

## II. MAJOR ASSUMPTIONS

The major assumptions upon which the program calculations are based are as follows:

a) There are two possible process stream configurations: a reverberatory furnace plus converter, with or without a roaster.

b) If a roaster is present, roaster and converter off-gases are combined for treatment at a single sulfuric acid plant, with input $SO_2$ concentration of five percent.

c) If a roaster is present, reverberatory off-gases are one percent $SO_2$, otherwise two percent $SO_2$.

d) Converter off-gases are treated alone in sulfuric acid plant at eight percent $SO_2$ when there is no roaster.

e) Reverberatory furnace off-gases are treated separately in a wet-lime venturi scrubber.

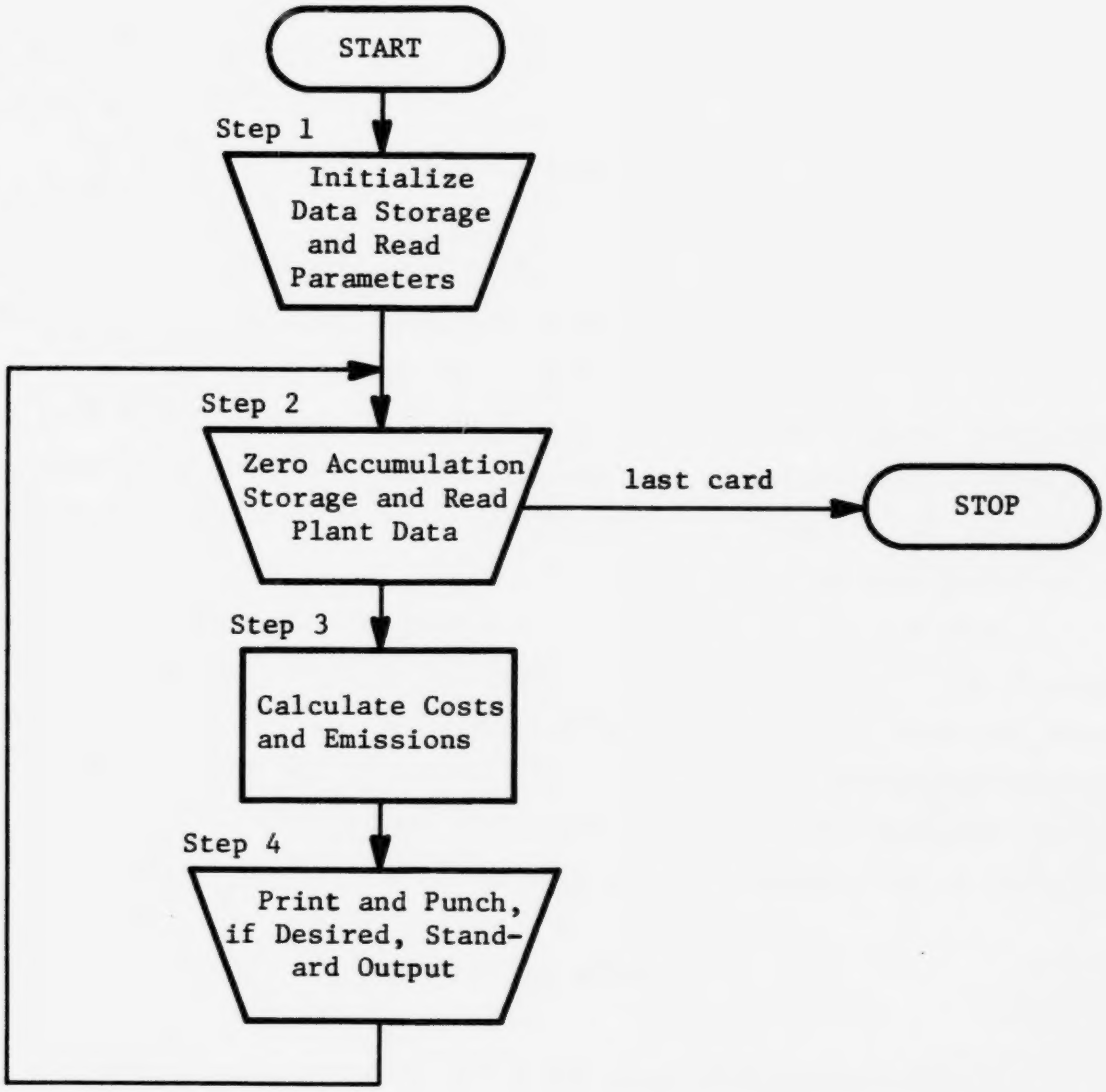

START
Step 1
Initialize Data Storage and Read Parameters
Step 2
Zero Accumulation Storage and Read Plant Data
last card
STOP
Step 3
Calculate Costs and Emissions
Step 4
Print and Punch, if Desired, Standard Output

Fig. P-1. Flow Chart for the Computer Program for Primary Copper

f) Table lookup and linear interpolation procedures within the table are adequate cost-calculating methods.

g) In 1967 some copper plants had sulfuric acid-producing equipment, and some did not.

h) No plant had a wet-lime venturi scrubber in 1967.

i) For the "model plant" and "total capacity" calculations, no sulfuric acid-producing equipment was present in 1967.

j) "Model plant" is defined as a single-stream plant with 25,000 SCFM off-gas from roaster (if present), 50,000 SCFM off-gas from converter, and 100,000 SCFM from reverberatory furnace.

k) Particulate emissions are controlled at the level required by the applicable standard.

Costs and emissions that have been calculated by the programs thus far are based on the above assumptions plus the capacity-cost-emission parameters described in Table P-1 and listed at the end of Section V.

Table P-1. - LIST OF PARAMETERS

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1-13 | | |
| COST(8,8,2) | Contains investment and annualized costs, and 1967 and final emissions, for plants with and without acid-making equipment, and with and without roasters, by capacity. | 1-80 | 10F8.0 |
| | Card 14 | | |
| SIZE(8) | Capacities corresponding to entries in COST. | 1-64 | 10F8.0 |

## III. PROGRAM LOGIC

Step numbers refer to the flow chart in Figure P-1.

Step 1.

Storage is initialized and the parameters are read in (see Table P-1).

Step 2.

Costs and emissions accumulation storage are zeroed. Data for one plant are read in (see Table P-2).

Step 3.

Costs and emissions are calculated (for each unit process within the plant, if required). For detailed plant data, the costs and emissions for each unit process are calculated from a linearly interpolated table versus capacity. Capacities are contained in SIZE, with corresponding costs and emissions in COST. Investment costs are accumulated in C1(1), annualized costs in C1(2), 1967 emissions of $SO_x$ in E1(1), and controlled emissions in E1(2).

If only plant capacity is known, the plant is assumed to have a roaster and to have no $SO_x$ control. Costs and emissions are calculated assuming that the plant has only one process stream (NPROC=1). Calculations are otherwise performed as for a plant with detailed data.

If only plant location is known, a "model plant" with roaster, no $SO_x$ control, and a pre-determined plant capacity is assumed. Calculations are otherwise performed as for a plant with detailed data.

Step 4.

Standard output, consisting of plant name and location, RSAC codes, costs, and emissions, are printed. Standard output is provided by Subroutine OUTFI. Control is transferred to Step 2. The program halts when the last card is read.

Table P-2. - LIST OF INPUT DATA

| FORTRAN Name | Description | Card Column | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| CTYPE | Card identification. | 1-2 | I2 |
| IAUX | Input type identification (0 for detailed data, 1 for total capacity data, 2 for model plant data). | 3 | I1 |
| IND | Industry number (32 for primary nonferrous: copper). | 4-5 | I2 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| NPROC | Number of different unit processes described on type 2 cards. | 11-12 | I2 |
| TOTCAP | Total plant capacity. | 13-22 | F10.0 |
| | Blanks. | 23-30 | 8X |
| INPUT(12) | Plant name and location. | 31-78 | 12A4 |
| | Card 2 | | |
| CTYPE | Card identification. | 1-2 | I2 |
| IAUX | Input type identification (0 for detailed data, 1 for total capacity data, 2 for model plant data). | 3 | I1 |
| IND | Industry number (32 for primary nonferrous: copper). | 4-5 | I2 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| DATA(6,4) | Data for up to 6 unit processes per plant. 1 is number of process streams with these data in plant; 2 is type number of this process (with or without roasters; 3 states whether or not there is an acid plant; 4 gives the actual capacity. | Col. 1:<br>11-12<br>31-32<br>51-52<br>Col. 2:<br>13-15<br>33-35<br>53-55<br>Col. 3:<br>16-17<br>36-37<br>56-57<br>Col. 4:<br>18-25<br>38-45<br>58-65 | |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| C1(2) | Vector for accumulating plant costs. |
| CAP | Temporary storage for capacity. |
| COST(8,8,2) | Array of costs and emissions used as table for table lookup. Index 1 specifies capacity corresponding to entry in vector SIZE. Index 2: "1-4" are for plant with roaster, "5-8" for plant without roaster; "1" and "5" for investment cost, "2" and "6" for annualized cost, "3" and "7" for 1967 emissions, "4" and "8" for controlled emissions. Index 3: "1" for plant without sulfuric acid-producing facility; "2" for plant with such facility. |
| CTYPE | Card type identification. |
| DATA(6,4) | Input data storage for detailed plant data. Up to 6 individual processes per plant. Column 1 number of the identical processes in the plant, Column 2 the process type number, Column 3 the code for sulfuric-acid facility, Column 4 the capacity of the process. |
| E1(2) | Vector for accumulating plant emissions. |
| F | Temporary storage for number of identical processes in the plant. |
| FRAC | Product of interpolation fraction and F. |
| I | Indexing variable. |
| IAUX | Input data type variable (0 for detailed data, 1 for capacity-only data, 2 for plant location-only data). |
| IND | Industry code (32 for primary copper). |
| INPUT(12) | Plant name and location. |
| IX | Storage for unit process type index. |
| IY | Storage for control type index. |
| J | Indexing variable. |
| NPLANT | Counter for number of plants processed. |
| NPROC | Number of unit processes described on card type 2 (IAUX=0 only). |
| OUTFI | Standard punched output subroutine. |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |

## V. LISTING OF THE COMPUTER PROGRAM FOR PRIMARY COPPER

```
C    Program Copper
C
C    THIS PROGRAM CALCULATES CONTROL COSTS AND EMISSIONS FOR THE PRIMARY
C    COPPER SMELTING INDUSTRY.
C
C    ALL COPPER SMELTERS HAVE A REVERBERATORY FURNACE AND CONVERTER (TYPE
C    1).  SOME ALSO HAVE A ROASTER.  THIS PROGRAM ASSUMES THATO (1) WHERE
C    A ROASTER IS PRESENT, THE ROASTER AND CONVERTER OFF-GASES ARE COM-
C    BINED FOR THE ACID PLANT TREATMENT AT 5( SOX, WITH FURNACE OFF-GASES
C    AT 1( SOX; (2) WHERE A ROASTER IS NOT PRESENT, CONVERTER OFF-GASES
C    ARE 8( SOX AND FURNACE OFF-GASES ARE 2( SOX; (3) FURNACE OFF-GASES
C    ARE SCRUBBED SEPARATELY IN A WET-LIME VENTURI SCRUBBER; (4) MODEL
C    PLANT OFF-GAS VOLUMES ARE 75,000 SCFM FOR ROASTER-CONVERTER, 50,000
C    SCFM FOR CONVERTER, AND 100,000 SCFM FOR REVERBERATORY FURNACE.
C    MODEL PLANT CALCULATIONS ASSUME ALL PLANTS NEED BOTH AN ACID PLANT
C    AND A WET-LIME SCRUBBER.
C
C    MATRIX COST CONTAINS A TABLE OF COSTS, WHICH ARE INTERPOLATED AS RE-
C    QUIRED.  C1 AND E1 ACCUMULATE COSTS AND EMISSION VALUES.
C
      DIMENSION INPUT(12), C1(2), E1(2), DATA(6,4), COST(8,8,2), SIZE(8)
      INTEGER  CTYPE
C
C    ZERO OUT DATA STORAGE
C
      DO 10 I=1,6
      DO 10 J=1,4
   10 DATA(I,J)=0.
      DO 20 I=1,8
      DO 20 J=1,8
      DO 20 K=1,2
   20 COST(I,J,K)=0.
      NPLANT=0
C
C    READ IN PARAMETERS
C
      READ 5000, COST
 5000 FORMAT(10F8.0)
      READ 5000, SIZE
C
C    READ IN CARD TYPE 1.
C
   30 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      READ 5005, CTYPE,IAUX, IND, RSAC1, RSAC2, NPROC, TOTCAP, INPUT
 5005 FORMAT(I2,  I1,I2,A4,A1,I2,F10.0,8X,12A4)
   40 IF (IND-32) 1010,50,1010
   50 IF (IAUX-1) 60,400,700
C
C    DETAILED PLANT DATA.
C
   60 READ 5010, CTYPE, IND, ((DATA(I,J),J=1,4),I=1,NPROC)
```

```
5010 FORMAT(  I2,1X,I2,5X,3(F2.0,F3.0,F2.0,F8.0,5X),10X,/,(10X,F2.0,
    1 F3.0,F2.0,F8.0))
      IF (CTYPE-2 ) 1000,70,1000
   70 IF (IND-32) 1010,80,1010
C
C   CALCULATE COSTS ANB EMISSIONS FOR DETAILED PLANT DATA.  DATA(I,1)
C   GIVES NUMBER OF PROCESS, DATA(I,2) STATES WHETHER THERE IS A ROASTER
C   AND DATA(I,3) STATES WHETHER THERE IS AN ACID PLANT.
C
   80 DO 110 I=1,NPROC
      F=DATA(I,1)
      IX=(DATA(I,2)-1.)*4.+1.
      IY=DATA(I,3)
      CAP=DATA(I,4)
      DO 100 J=2,12
      IF (CAP-SIZE(J)) 90,100,100
   90 FRAC=CAP/SIZE(J)*F
      C1(1)=COST(J,IX,IY)*FRAC
      C1(2)=COST(J,IX+1,IY)*FRAC
      E1(1)=COST(J,IX+2,IY)*FRAC
      E1(2)=COST(J,IX+3,IY)*FRAC
      GO TO 110
  100 CONTINUE
      GO TO 200
  110 CONTINUE
      GO TO 30
  200 PRINT 5015, I, RSAC1, RSAC2, INPUT
 5015 FORMAT(37H CAPACITY TOO LARGE ON FURNACE NUMBER,I4,/,10H PLANT0
    1, A4,A1,2X,12A4)
      NPLANT=NPLANT+1
      GO TO 30
      CALL OUTFI(RSAC1,RSAC2,AQCR,31,INPUT,C1,1,2,E1)
      AQCR==20202020
C
C   PLANT CAPACITY KNOWN.  ONE PROCESS STREAM WITH ROASTER ASSUMED.
C
  400 NPROC=1
      DATA(1,1)=1.
      DATA(1,2)=1.
      DATA(1,3)=1.
      DATA(1,4)=TOTCAP
      GO TO 80
C
C   MODEL PLANT CALCULATION.  SIMILAR TO ABOVE, WITH MODEL PLANT CAPA-
C   CITY.
C
  700 DATA(1,1)=1.
      DATA(1,2)=1.
      DATA(1,3)=1.
      DATA(1,4)=20000.
      NPROC=1
      GO TO 80
C
C   ERROR ROUTINES
C
 1000 PRINT 5020, CTYPE, RSAC1, RSAC2, INPUT
 5020 FORMAT(11H CARD TYPE ,F3.0,26H OUT OF ORDER.  PLANT IDO ,A4,A1,1X,
    1 12A4)
      GO TO 30
 1010 PRINT 5025, IND, RSAC1, RSAC2, INPUT
 5025 FORMAT(15H INDUSTRY CODE,I4,20H, INVALID FOR PLANT ,A4,A1,1X,12A4)
      GO TO 30
C
C     FINAL OUTPUT.
C
 2000 PRINT 5030, NPLANT
 5030 FORMAT(28H-NUMBER OF PLANTS PROCESSED ,I5)
      STOP
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

# APPENDIX Q

## Primary Nonferrous Metallurgy: Lead

# Appendix Q

## Primary Nonferrous Metallurgy: Lead

### I. INTRODUCTION

The primary lead industry produces metallic lead from ores. The emission for which control costs and amount of emissions are calculated by this program is sulfuroxide primarily as sulfur dioxide. Costs are calculated using a table lookup procedure when detailed plant data are available. The program is designed to use model plant calculating techniques (when IAUX = 2), total plant capacity techniques (when IAUX = 1), or detailed data techniques (when IAUX = 0).

Figure Q-1 is a flow chart for the program.

The remainder of this Appendix is organized as follows: Section II lists the assumptions on which the program is based in detail; Section III describes the actual program operations; Section IV is a glossary of the FORTRAN names used in the program; and Section V contains a listing of the program, followed by the parameters used thus far.

### II. MAJOR ASSUMPTIONS

The major assumptions upon which the program calculations are based are:

a) Smelter.

b) Table lookup and linear interpolation procedures within the table are adequate cost-calculating methods.

c) No plant had a wet-line venturi scrubber in 1967.

d) For the "model plant" and "total capacity" calculations, no sulfuric acid-producing equipment was present in 1967.

e) "Model plant" is defined as a single-stream plant with 20,000 tons/day capacity.

f) Annualized costs for the sulfuric acid facility are recovered by sale of acid.

g) Particulate emissions are controlled at the level required by the applicable standard.

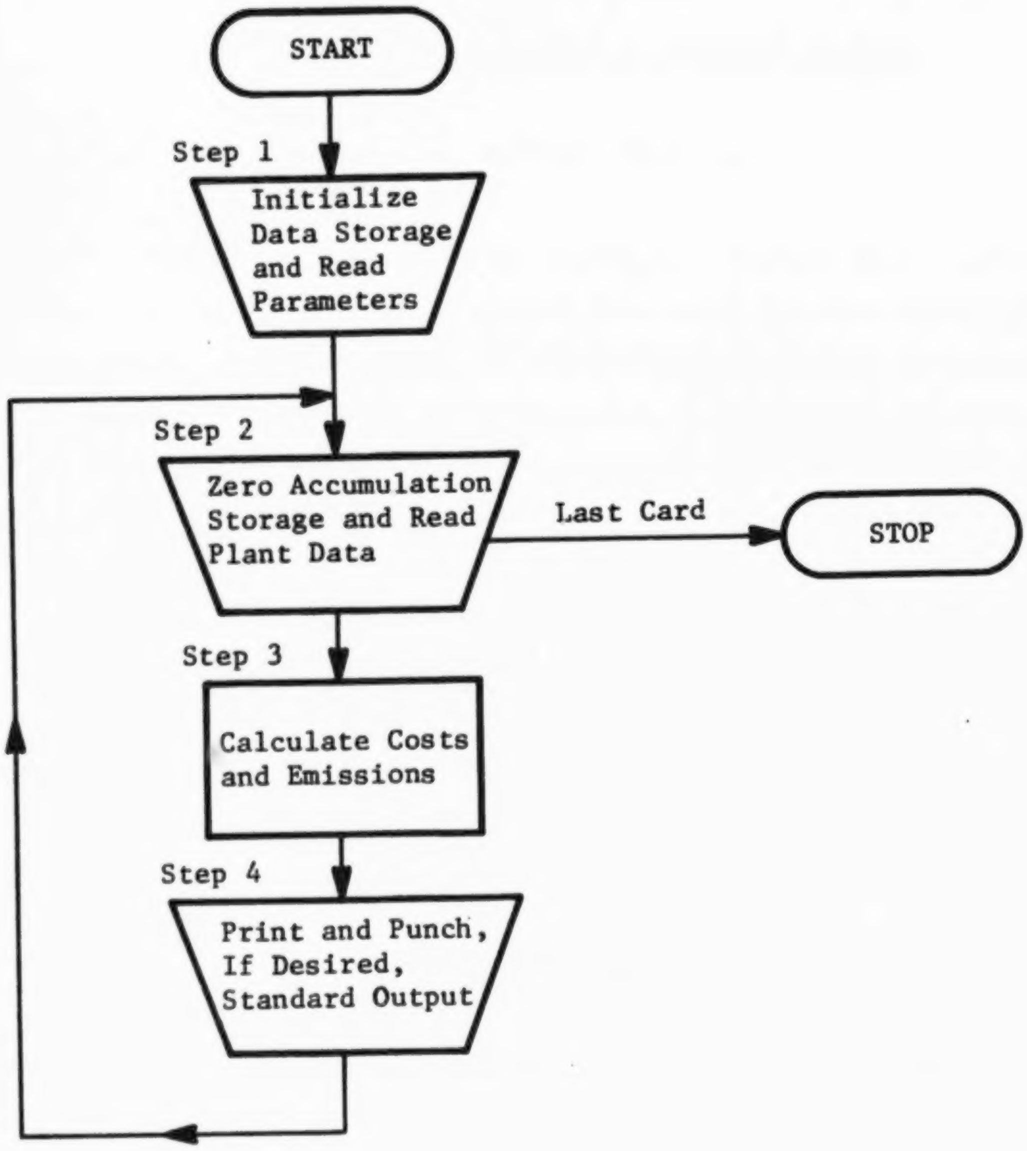

START
Step 1
Initialize Data Storage and Read Parameters
Step 2
Zero Accumulation Storage and Read Plant Data
Last Card
STOP
Step 3
Calculate Costs and Emissions
Step 4
Print and Punch, If Desired, Standard Output

Fig. Q-1. Program Flow Chart for the Computer Program for Primary Lead.

Costs and emissions that have been calculated by the program thus far are based on the above assumptions plus the capacity-cost-emission parameters described in Table Q-1 and Listed at the end of Section V.

TABLE Q-1. - LIST OF PARAMETERS

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1 - 11 | | |
| COST(12,9) | Contains investment and annualized costs, and 1967 and final emissions, for plants with and without acid-making equipment, by capacity. Entries in column 1 are 12 capacities. Columns 2 and 6 contain corresponding investment costs for a plant with and without an acid facility in 1967; columns 3 and 7 contain corresponding annualized costs; columns 4 and 8, and 5 and 9, contain corresponding 1967, and final, emissions. | 1-80 | 12F6.0 |

## III. PROGRAM LOGIC

Step numbers refer to the flow chart in Figure Q-1.

Step 1.

Storage is initialized and the parameters are read in (see Table Q-1).

Step 2.

Costs and emissions accumulation storage are zeroed. Data for one plant are read in (see Table Q-2).

Step 3.

Costs and emissions are calculated (for each unit process within the plant, if required). For detailed plant data, the costs and emissions for each unit process are calculated from a linearly interpolated table versus capacity. Capacities are contained in column 1 of COST, with corresponding costs and emissions in columns 2-9. Investment costs are accumulated in C1(1), annualized costs in C1(2), 1967 emissions of $SO_x$ in E1(1), and controlled emissions in E1(2).

If only plant capacity is known, the plant is assumed to have no $SO_x$ control. Costs and emissions are calculated assuming that the plant has only one process stream (NPROC = 1). Calculations are otherwise performed as for a plant with detailed data.

If only plant location is known, a "model plant" with no $SO_x$ control and pre-determined plant capacity is assumed. Calculations are otherwise performed as for a plant with detailed data.

Step 4.

Standard output, consisting of plant name and location, RSAC codes, costs, and emissions, is printed. Standard output is provided by Subroutine OUTFI. Control is transferred to Step 2. The program halts when the last card is read.

TABLE Q-2 - LIST OF PLANT INPUT DATA

| FORTRAN Name | Description | Card Column | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| | Blank. | 1 | IX |
| CODE | Card identification. | 2 | I1 |
| IAUX | Input type identification (0 for detailed data, 1 for total capacity data, 2 for model plant data). | 3 | I1 |
| IND | Industry number (3 for primary nonferrous: Lead | 4-5 | I2 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| FSAC2 | RSAC part code. | 10 | A1 |
| NPROC | Number of different unit processes described on type 2 cards. | 10-12 | I2 |
| TOTCAP | Total plant capacity. | 13-22 | F10.0 |
| | Blanks. | 23-30 | 8X |
| INPUT(12) | Plant name and location. | 31-78 | 12A4 |
| | Card 2 | | |
| | Same as card type 1. | 1-10 | |
| DATA (6,4) | Data for up to 6 unit processes per slant: 1 is number of process streams with these data in plant; 2 is type number of this process with or without ratios; 3 states whether or not there is an acid plant; 4 gives the actual capacity. | Col. 1:11-12, 31-32,51-52<br>Col. 2:13-15, 33-35,53-55<br>Col. 3:16-17 36-37,56-57<br>Col. 4:18-25 38-45,58-65 | F2.0<br>F3.0<br>F2.0<br>F8.0 |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| C1(2) | Vector for accumulating plant costs. |
| COST(12,9) | Array of costs and emissions used as table look-up (see Table Q-1). |
| CODE | Card type identification. |
| DATA(6,4) | Input data storage for detailed plant data. Up to 6 individual processes per plant. Column 1 is the number of the identical processes in the plant; column 2 is the process type number; column 3 is the code for sulfuric-acid facility; column 4 is the capacity of the process. |
| E1(2) | Vector for accumulating plant emissions. |
| F | Interpolation fraction. |
| I | Indexing variable. |
| IAUX | Input data tpe variable (0 for detailed data; 1 for capacity-only data; 2 for plant location-only data). |
| IND | Industry code (33 for primary nonferrous lead). |
| INPUT(12) | Plant name and location. |
| IX | Storage for unit process type index. |
| J | Indexing variable. |
| NPROC | Number of unit processes described on card type 2 (IAUX=0 only). |
| OUTFI | Standard punched output subroutine. |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC plant code. |

## V. LISTING OF THE COMPUTER PROGRAM FOR PRIMARY LEAD

```
C    PROGRAM LEAD
C    THIS PROGRAM CALCULATES COSTS AND EMISSIONS FOR CONTROLLING LEAD
C    SMELTERS.
C
C    THE POLLUTANT TO BE CONTROLLED IS SULFUR DIOXIDE.  ARRAY COST CON-
C    TAINS BOTH COSTS AND EMISSIONS FOR A SMELTER WITH OR WITHOUT AN ACID
C    PLANT INSTALLED, BY CAPACITY.  AN INTERPOLATION IS DONE TO FIND
C    EXACT VALUES.  WET-LIME SCRUBBING MUST BE ADDED TO ALL PLANTS.
C
C    SEPARATE ROUTINES ARE PROVIDED FOR MODEL PLANT (IAUX=2), DETAILED
C    PLANT DATA (IAUX=0), AND TOTAL CAPACITY KNOWN (IAUX=1) SITUATIONS.
      DIMENSION INPUT(12), C1(2), E1(2), DATA(6,4), COST(12,9)
      INTEGER CODE
C
C
C    ZERO DATA STORAGE
C
      DO 10 I=1,6
      DO 10 J=1,4
      DATA(I,J)=0.
   10 CONTINUE
      DO 20 I=1,12
      DO 20 J=1,9
      COST(I,J)=0.
   20 CONTINUE
      AQCR=0
C
C    READ COST PARAMETERS.
C
      READ 5000, COST
 5000 FORMAT(10F8.0)
C
C    READ PLANT DATA.
C
   30 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      READ 5005, CODE, IAUX,   IND, RSAC1, RSAC2, NPROC, TOTCAP, INPUT
 5005 FORMAT( 1X,2I1,I2, A4,A1,I2,F10.0,8X,12A4)
      IF (CODE-1 ) 2000,40,1000
   40 IF (IND-33) 1010,50,1010
   50 IF (IAUX-1) 60,700,400
C
C    READ DETAILED DATA
C
   60 READ 5010, CODE, IND,  ((DATA(I,J),J=1,4),I=1,NPROC)
 5010 FORMAT(1X,I1,1X,I2, 5X,3(F2.0,F3.0,F2.0,F8.0,5X),/,10X,3(F2.0,F3.0
     1,F2.0,F8.0,5X))
      IF (CODE-2 ) 1000,70,1000
   70 IF (IND-33) 1010,80,1010
C
C    PROCESS DETAILED DATA
```

```
C
   80 DO 100 I=1,NPROC
      DO 100 J=1,12
      IF (DATA(I,4)-COST(J,1)) 90,100,100
   90 IX=DATA(I,1)-1.
      IX=IX*4+2
      F=(COST(J,1)-DATA(I,4))*DATA(I,2)/COST(J,1)
      C1(1)=C1(1)+COST(J,IX)*F
      C1(2)=C1(2)+COST(J,IX+1)*F
      E1(1)=E1(1)+COST(J,IX+2)*F
      E1(2)=E1(2)+COST(J,IX+3)*F
  100 CONTINUE
  110 CALL OUTFI(RSAC1,RSAC2,AQCR,33,INPUT,C1,1,2,E1)
      PRINT 4999, RSAC1, RSAC2, INPUT, C1, E1
 4999 FORMAT(1X,A4,A1,12A4,4F10.2)
      GO TO 30
C
C   MODEL PLANT CALCULATION
C
  400 NPROC=1
      DATA(1,1)=1.
      DATA(1,2)=1.
      DATA(1,3)=1.
      DATA(1,4)=20000.
      GO TO 80
C
C   TOTAL CAPACITY CALCULATION.
C
  700 NPROC=1
      DATA(1,1)=1.
      DATA(1,2)=1.
      DATA(1,3)=1.
      DATA(1,4)=TOTCAP
      GO TO 80
C
C   ERROR ROUTINES.
C
 1000 PRINT 5015, CODE, RSAC1, RSAC2, INPUT
 5015 FORMAT(11H CARD TYPE ,F3.0,26H OUT OF ORDER.  PLANT IDO ,A4,A1,1X,
     1 12A4)
      GO TO 30
 1010 PRINT 5025, IND, RSAC1, RSAC2, INPUT
 5025 FORMAT(15H INDUSTRY CODE,I4,20H, INVALID FOR PLANT ,A4,A1,1X,12A4)
      GO TO 30
      NPLANT=0
      NPLANT=NPLANT+1
C
C   FINAL OUTPUT
C
 2000 PRINT 5030, NPLANT
 5030 FORMAT(28H1NUMBER OF PLANTS PROCESSED ,I5)
      STOP
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

## APPENDIX R

## Primary Nonferrous Metallurgy: Zinc

# Appendix R

## Primary Nonferrous Metallurgy: Zinc

### I. INTRODUCTION

The primary zinc industry produces metallic zinc from ores. The emission for which control costs and emissions are calculated by this program is sulfur oxide primarily as sulfur dioxide. Costs are calculated using a table lookup procedure when detailed plant data are available. The program is designed to use plant data in detailed format only.

The remainder of this appendix is organized as follows: Section II lists the assumptions on which the program is based in detail; Section III describes the actual program operations; Section IV is a glossary of the FORTRAN names used in the program; and Section V contains a listing of the program, followed by the parameters used thus far.

Figure R-1 is a flow chart for the program.

### II. MAJOR ASSUMPTIONS

The major assumptions upon which the program calculations are based are as follows:

1) There are two possible process stream configurations: a roaster (a) with or (b) without a sintering machine.
2) If a sintering machine is present, sintering and roaster off-gases are combined for treatment at a single sulfuric acid plant, with input $SO_2$ concentration of five percent.
3) Table lookup and linear interpolation procedures within the table are adequate cost-calculating methods.
4) In 1967, some zinc plants had sulfuric acid-producing equipment and some did not.
5) If a sulfuric-acid facility was present in 1967, no costs are assigned.
6) Particulate emissions are controlled at the level required by the applicable standard.

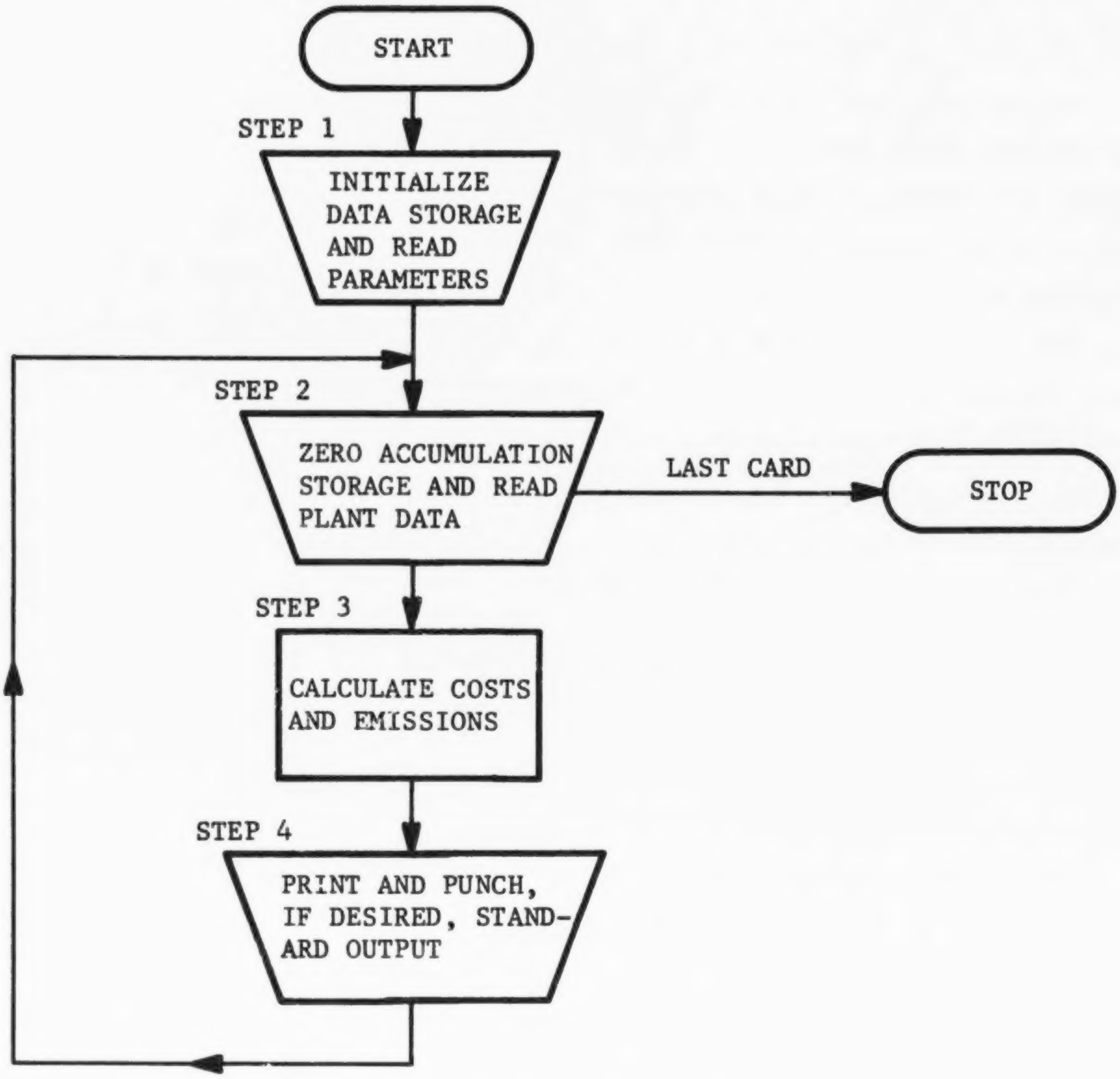

START
STEP 1
INITIALIZE DATA STORAGE AND READ PARAMETERS
STEP 2
ZERO ACCUMULATION STORAGE AND READ PLANT DATA
LAST CARD
STOP
STEP 3
CALCULATE COSTS AND EMISSIONS
STEP 4
PRINT AND PUNCH, IF DESIRED, STANDARD OUTPUT

Fig. R-1.- Flow Chart for the Computer Program for Primary Zinc.

Costs and emissions that have been calculated by the program thus far are based on the above assumptions plus the capacity-cost-emission parameters described in Table R-1 and listed at the end of Section V.

Table R-1. - LIST OF PARAMETERS

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1-4 | | |
| COST(2,2,10) | Contains investment and annualized costs for plants without acid-making equipment and with and without sintering machines by capacity. | 1-80 | 10F8.0 |
| | Card 5 | | |
| SIZE(10) | Capacities corresponding to entries in COST. | 1-80 | 10F8.0 |
| EM(2,2) | Emission factors for plants with and without sintering machines, with and without acid plants. | 1-32 | 4F8.0 |

## III. PROGRAM LOGIC

Step numbers refer to the flow chart in Figure R-1.

Step 1.

Storage is initialized and the parameters are read in (see Table R-1).

Step 2.

Costs and emissions accumulation storage are zeroed. Data for one plant are read in (see Table R-2).

Step 3.

Costs and emissions are calculated for each unit process within the plant. The costs for each unit process are calculated from a linearly interpolated table versus capacity. Capacities are contained in SIZE, with corresponding costs and emissions in COST. Investment costs are accumulated in C1(1), annualized costs in C1(2). $SO_2$ emissions are calculated from emission factors and unit process capacity. Emissions of $SO_2$, in 1967) in E1(1), and controlled emissions in E1(2).

Table R-2. - LIST OF PLANT INPUT DATA

| FORTRAN Name | Description | Card Column | FORTRAN Format |
|---|---|---|---|
|  | Card 1 |  |  |
|  | Blank. | 1 | IX |
| ICODE | Card identification | 2 | I1 |
| IAUX | Input type identification not used used. | 3 | I1 |
| SCOPE | Industry number (34 for primary nonferrous: zinc). | 4-5 | I2 |
| RSAC1 | RSAC code. 6-9 | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| NPROC | Number of different unit processes described on type 2 cards. | 11-12 | I2 |
| TOTCAP | Total plant capacity. | 13-22 | F10.0 |
|  | Blanks. | 23-30 | 8X |
| INPUT(12) | Plant name and location. | 31-78 | 12A4 |
|  | Card 2 |  |  |
|  | Same as Card type 1. | 1-10 |  |
| iUNIT(10) | Process type identification ("1"-with sintering machine, "2" without sintering machine) for up to 10 unit processes per plant. | 11-12,<br>31-32,<br>51-52 | I2 |
| XNO(10) | Number of processes of this type in plant. | 13-15,<br>33-35,<br>53-55 | F3.0 |
| EFF(10) | Corresponding control efficiency applied to this process in 1967. | 16-17<br>36-37,<br>56-57 | F2.0 |
| CAP(10) | Corresponding unit process capacity. | 18-25,<br>28-45,<br>58-65 | F8.0 |
|  | Blanks. | 26-30,<br>46-50,<br>66-70 | 5X |

Step 4.

Standard output, consisting of plant name and location, RSAC codes, costs, and emissions, is printed. Standard output is provided by Subroutine OUTFI. Control is transferred to Step 2. The program halts when the last card is read.

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| C | Temporary storage for CAP(10) |
| C1(2) | Vector for accumulating plant costs. |
| CAP(10) | Input storage for capacity (see Table R-2). |
| COST(2,2,10) | Array of costs and emissions used as table for table lookup. Index 3 specifies capacity corresponding to entry in vector, SIZE. Index 2: "1" for plant with sintering machine; "2" for plant without; Index 1: "1" for plant with sulfuric acid-producing facility; "2" for plant without such facility. |
| D. | Temporary storage for XNO(10) |
| E | Temporary storage for 1967 control efficiency. |
| E1(2) | Vector for accumulating plant emissions. |
| EM(2,2) | $SO_2$ emission factors (see Table R-1). |
| EFF(10) | Input storage for 1967 unit process control efficiency (see Table R-2). |
| I | Indexing variable. |
| IAUX | Input data type variable (not used). |
| IUNIT(10) | Unit process type number (see Table R-2). |
| INPUT(12) | Plant name and location. |
| IT | Storage for unit process type index. |
| J | Indexing variable. |

| | |
|---|---|
| J1,J2 | Temporary variables. |
| MPROC | Temporary variable. |
| NPROC | Number of unit processes described on cards type 2. |
| OUTFI | Standard punched output subroutine. |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |
| SCODE | Industry code (34 for Primary Zinc). |
| XNO(10) | Number of units of a process within a single plant (see Table R-2). |

## V. LISTING OF THE COMPUTER PROGRAM FOR PRIMARY ZINC

```
C     PROGRAM ZINC
C     THIS PROGRAM CALCULATES COSTS AND EMISSIONS ASSOCIATED WITH PRIMARY
C     ZINC SMELTERS.
C
C     EVERY ZINC PLANT CONTAINS A ROASTER.  SOME ALSO HAVE A SINTERING
C     MACHINE.  PLANTS WITH SINTERING MACHINES ARE IDENTIFIED AS TYPE 1,
C     WITHOUT AS TYPE 2.  PLANT TYPE IS USED AS AN INDEX FOR TABLE LOOK-UP
C     PROCEDURES, ALONG WITH PLANT CAPACITY.
C
C     THE EMISSIONS FROM ZINC PLANTS ARE ASSUMED TO BE SO2 ONLY.  CONTROL
C     IS BY INSTALLATION OF AN ACID PLANT.  CONTROL EFFICIENCIES RESULTING
C     ARE 92( FOR TYPE 1, 96( FOR TYPE 2; THESE ARE ASSUMED TO BE ADEQUATE
C
C     EM(2,2) CONTAINS EMISSION FACTORS FOR BEFORE AND AFTER EMISSION
C     LEVELS FOR THE TWO PROCESS TYPES.  COST(2,2,10) CONTAINS INVESTMENT
C     AND ANNUAL COSTS FOR THE TEN UNIT PROCESS SIZES IN SIZE(10).  LINEAR
C     INTERPOLATION IS DONE BETWEEN THESE VALUES.
C
C     PLANT COSTS ARE ACCUMULATED IN C1(2), EMISSIONS IN E1(2).
C
      DIMENSION IUNIT(10), CAP(10), EFF(10), EM(2,2), XNO(10), SIZE(10),
     1 COST(2,10), INPUT(12)
      INTEGER SCODE
      DO 10 I=1,10
      IUNIT(I)=0
      CAP(I)=0.
      EFF(I)=0.
      XNO(I)=0.
      SIZE(I)=0.
      DO 10 J=1,2
      COST(J,I)=0.
   10 CONTINUE
C
C     READ PARAMETERS
C
      READ 5000, SIZE, COST, EM
 5000 FORMAT(10F8.0)
C
C     READ DATA FOR ONE PLANT
C
   20 C1(1)=0.
      C1(2)=0.
      E1(1)=0.
      E1(2)=0.
      READ 5005, ICODE, IAUX, SCODE, RSAC1, RSAC2, NPROC, TOTCAP, INPUT
 5005 FORMAT(1X,2I1,I2,A4,A1,I2,F10.0,8X,12A4)
      IF (ICODE-1) 2000,21,1000
   21 IF (SCODE-34) 1010,22,1010
   22 MPROC=NPROC/3
      LPROC=NPROC-MPROC*3
      IF (MPROC) 50,50,30
   30 DO 40 I=1,MPROC
      J1=(I-1)*3+1
      J2=J1+2
      READ 5010, (IUNIT(J),XNO(J),EFF(J),CAP(J),J=J1,J2)
 5010 FORMAT(10X,I2,F3.0,F2.0,F8.0,5X,I2,F3.0,F2.0,F8.0,5X,I2,F3.0,F2.0,
     1 F8.0)
   40 CONTINUE
      IF (LPROC) 60,60,50
   50 MPROC=MPROC*3+1
      READ 5010, (IUNIT(J),XNO(J),EFF(J),CAP(J),J=MPROC,NPROC)
C
C   CALCULATE COSTS AND EMISSIONS
C
      DO 110 I=1,NPROC
      IT=IUNIT(I)
      D=XNO(I)
      E=EFF(I)
      C=CAP(I)
      IF (E-EM(IT,2)) 60,100,100
C
C   FIND CAPACITY IN SIZE LIST.
C
   60 DO 70 J=2,10
      IF (C-SIZE(J)) 80,90,70
   60 CONTINUE
      D=D*2.
      C=C/2.
      GO TO 60
   70 FACT=(SIZE(J)-C)/(SIZE(J)-SIZE(J-1))
      GO TO 90
   80 FACT=1.
   90 C1(1)=FACT*COST(1,IT,J)*D+C1(1)
      C1(2)=FACT*COST(2,IT,J)*D+C1(2)
  100 E1(1)=E1(1)+EM(IT,1)*(1.0-(E/100.))*D*C
      E1(2)=E1(2)+EM(IT,2)*D*C
  110 CONTINUE
C
C   OUTPUT ROUTINE
C
      PRINT 5015, INPUT, E, TOTCAP, C1, E1
 5015 FORMAT(12A4,F4.0,5F12.2)
      CALL OUTFI(RSAC1,RSAC2,AQCR,34,C1,1,2,E1)
      GO TO 20
C
C   ERROR ROUTINES
C
 1000 PRINT 5020, ICODE, RSAC1, RSAC2
 5020 FORMAT(19H INVALID CARD CODE ,I2,15H FOUND IN CARD ,A4,A1)
      GO TO 20
 1010 PRINT 5025, SCODE, RSAC1, RSAC2
 5025 FORMAT(21H INVALID SOURCE CODE ,I3,15H FOUND IN CARD ,A4,A1)
      GO TO 20
C
C   END ROUTINE
C
 2000 PRINT 5030
 5030 FORMAT(12H1GOOD FINISH)
      STOP
      END
```

DATA IDENTIFIED IN THE LIST OF PARAMETERS.

# APPENDIX S

## Computer Program for Secondary Nonferrous Metallurgy

# Appendix S

## Computer Program for Secondary Nonferrous Metallurgy

### I. INTRODUCTION

Secondary nonferrous metallurgy is basically scrap metals recovery. Many different furnace types are used in the smelting of scrap. Over a period of time, emissions vary even within a particular plant because of the heterogenous nature of the scrap being processed. The recovery nonferrous metals considered in this report are the same as the primary nonferrous metals considered: aluminum, copper, lead, and zinc.

The data currently available for all plants is only that of plant location. Therefore, for program flexibility, model plant calculations and total capacity calculations for each of the four metals are included along with the detailed plant data method.

The remainder of this appendix is organized as follows: Section II lists the assumptions on which the program is based; Section III describes the actual program operations; Section IV is a glossary of FORTRAN names used in the program; and Section V contains a listing of the program followed by the parameters currently used.

Figure S-1 is a flow chart of the program.

### II. ASSUMPTIONS

The assumptions on which the program operations are based are:

a) Particulate emissions are the only ones requiring control.

b) Table lookup with linear interpolation is adequate for calculating costs.

c) Where total capacity is given as the only process size datum, there is one process stream per plant.

### III. PROGRAM OPERATIONS

Step numbers refer to the flow chart in Figure S-1.

Step 1.

Storage is initialized and parameters are read in (see Table S-1).

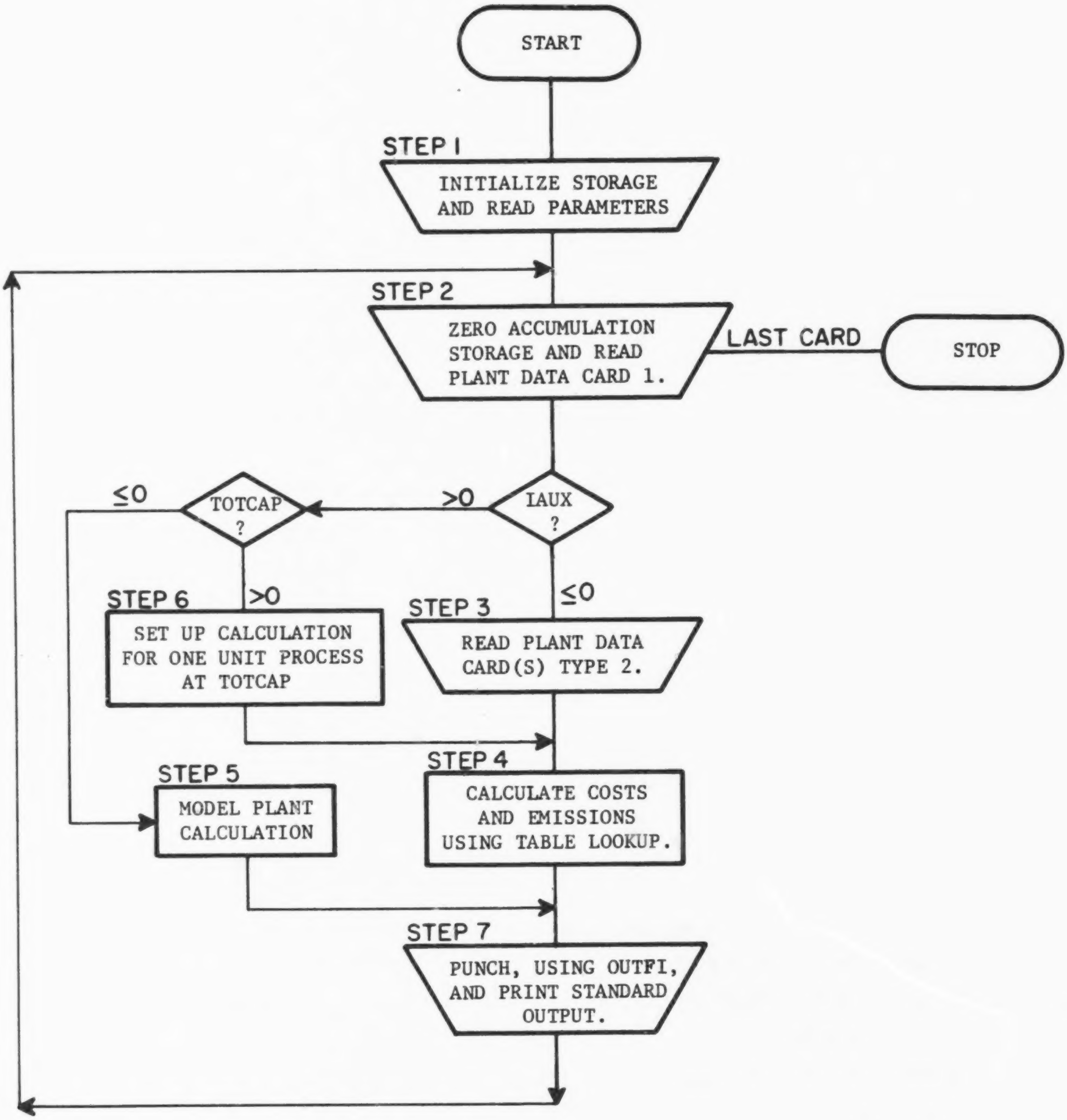

START
STEP 1
INITIALIZE STORAGE AND READ PARAMETERS
STEP 2
ZERO ACCUMULATION STORAGE AND READ PLANT DATA CARD 1.
LAST CARD
STOP
IAUX ?
>0
≤0
TOTCAP ?
≤0
>0
STEP 6
SET UP CALCULATION FOR ONE UNIT PROCESS AT TOTCAP
STEP 3
READ PLANT DATA CARD(S) TYPE 2.
STEP 4
CALCULATE COSTS AND EMISSIONS USING TABLE LOOKUP.
STEP 5
MODEL PLANT CALCULATION
STEP 7
PUNCH, USING OUTFI, AND PRINT STANDARD OUTPUT.

Fig. S-1. - Flow Chart for Secondary Nonferrous Metallurgy Computer Program.

TABLE S-1. - LIST OF PARAMETERS

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Cards 1-16 | | |
| SIZE(4,10) | SIZE contains 4 rows of 10 entries each. One row is a list of process capacities for each of the 4 metals: (1) copper, (2) aluminum, (3) zinc, and (4) lead. COST1 and COST2 contain the corresponding investment and annualized costs of control. EFF contains the corresponding resulting control efficiency as a percent. Entries are to be interspersed in the order SIZE(1,1), COST1(1,1), COST2(1,1), EFF(1,1), SIZE(1,2), COST1(1,2), . . . | 1-80 | 8F10.0 |
| | Card 17 | | |
| DEFF(4) | Emission factors as a decimal fraction of capacity for each of the four unit processes. | 1-40 | 4F10.0 |

Step 2.

Costs and emission accumulation storage is set to zero. Data card type 1 is read (see Table S-2). If $IAUX \leq 0$, control is transferred to Step 3. If $IAUX > 0$, and $TOTCAP > 0$, control is transferred to Step 6. If $IAUX > 0$ and $TOTCAP \leq 0$, control is transferred to Step 5.

Step 3.

Data card(s) type 2 are read (see Table S-3).

Step 4.

Table lookups for investment and annualized costs are performed with linear interpolation, where necessary, for each unit process. Costs for accumulated for plant totals. Control is transferred to Step 7.

Step 5.

Model plant calculation. A specified value, selected by metal type code (IAUX), is assigned to each of the plant costs and emissions. Control is transferred to Step 7.

Step 6.

A "detailed data" calculation is initiated with one unit process of type specified by the value of IAUX. Capacity is taken to be TOTCAP, with initial (1967) control efficiency of zero. Control is transferred to Step 4.

Step 7.

Standard plant output is printed and subroutine OUTFI is called to punch standard plant output. Control is transferred to Step 2 to begin the next plant's data readin. The program stops when the last card is read.

## TABLE S-2. - DESCRIPTION OF PLANT INPUT DATA

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | **Card Type 1** | | |
| | Blank | 1 | 1X |
| ICODE | Card type identification. | 2 | I1 |
| IAUX | Data type identification 0 for detailed data requiring card(s) type 2. 1, 2, 3, or 4 for either model plant or total capacity calculation. 1 is for copper plant, 2 for aluminum, 3 for zinc, 4 for lead. | 3 | I1 |
| SCODE | Industry code (21 for secondary nonferrous metallurgy). | 4-5 | F2.0 |
| RSAC1 | RSAC code. | 6-9 | A4 |
| RSAC2 | RSAC part code. | 10 | A1 |
| TOTCAP | Total plant capacity. Zero value identifies model plant calculation. | 11-20 | F10.0 |
| NPROC | Number of unit processes to be read from card(s) type 2. | 21-22 | I2 |
| | Blanks | 23-30 | 8X |
| INPUT(12) | Plant name and location | 31-78 | 12A4 |
| | **Card Type 2** | | |
| | Same as card type 1. | 1-10 | |
| IUNIT(2,10) | For up to 10 unit processes, row 1 contains metal type (same as for IAUX); row 2 contains number of such unit process in the plant. | 11-12, 31-32,<br>51-52 | I2<br>I3 |
| CEFF(10) | For up to 10 unit processes, 1967 control efficiency. | 16-17, 36-37, | F2.0 |
| CAP(10) | For up to 10 unit processes, process capacity. | 18-25, 38-45<br>58-65 | F8.0 |
| | Blanks | 26-30, 46-50,<br>66-70 | 5X |

## IV. GLOSSARY OF FORTRAN NAMES

| FORTRAN Name | Definition |
|---|---|
| C1(2) | Vector for accumulation of plant costs. |
| CAP(10) | Input storage for capacities (see Table S-2). |
| CEFF(10) | Input storage for control efficiencies (see Table S-2). |
| COST1(4,10) | Table of investment costs (see Table S-1). |
| COST2(4,10) | Table of annualized costs (see Table S-1). |
| DEL | Temporary storage for number of processes. |
| EFF(4,10) | Table of final control efficiencies (see Table S-1). |
| FRAC | Interpolation fraction. |
| I | Indexing variable. |
| ICODE | Card type identification. |
| INPUT(12) | Input storage for plant name and location (see Table S-2). |
| IUNIT(2,10) | Input storage for plant data (see Table S-2). |
| J | Indexing variable. |
| NPROC | Number of plant unit processes. |
| RSAC1 | RSAC code. |
| RSAC2 | RSAC part code. |
| SCODE | Industry code (21 for secondary nonferrous metallurgy). |
| SIZE(4,10) | Table of capacities (see Table S-1). |
| TOTCAP | Input storage for plant capacity (see Table S-2). |

## V. LISTING OF THE COMPUTER PROGRAM FOR SECONDARY NONFERROUS

```
C     PROGRAM SECNON
C     THIS PROGRAM CALCULATES CONTROL COSTS AND EMISSIONS FOR SECONDARY
C     NON-FERROUS METAL REFINING.
C
C     IUNIT CONTAINS PROCESS TYPE IDENTIFICATION (1-COPPER, 2-ALUMINUM,
C     3-ZINC, 4-LEAD) AND CAPACITY CONTAINS PROCESS SIZE.  COST IS CALCUL-
C     ATED ON A STRAIGHT-LINE DOLLARS PER UNIT CAPACITY TECHNIQUE WITH DE-
C     TAILED DATA.  MODEL PLANTS USED OTHERWISE.
C
      DIMENSION INPUT(12), IUNIT(10), CEFF(10), CAP(10), C1(2), E1(2)
      DIMENSION SIZE(4,10), COST1(4,10), COST2(4,10), EFE(4,10), DEFF(4)
C
C     INITIALIZE
C
      DO 10 I=1,10
      IUNIT(I)=0
      CEFF(I)=0.0
      CAP(I)=0.0
   10 CONTINUE
      READ 5001,((SIZE(I,J),COST1(I,J),COST2(I,J),EFF(I,J),J=1,10),
     1 I=1,4), DEFF
 5001 FORMAT(8F10.0)
C
C     READ CARD TYPE 1.
C
   20 C1(1)=0.0
      C1(2)=0.0
      E1(1)=0.0
      E1(2)=0.0
      READ 5000, ICODE, IAUX, SCODE, RSAC1, RSAC2, TOTCAP, NPROC, INPUT
 5000 FORMAT(1X,2I1,F2.0,A4,A1,F10.0,I2,8X,12A4)
      IF (ICODE-1) 2000,30,1000
   30 IF (SCODE-21.) 1010,40,1010
C
C     CALCULATION WHERE PLANT CAPACITY IS KNOWN
C
   40 IF (IAUX) 50,50,65
   50 READ 5005, ICODE, SCODE,((IUNIT(J,I),J=1,2),CEFF(I),CAP(I),I=1,10)
 5005 FORMAT(1X,I1,1X,F2.0,5X,3(I2,I3,F2.0,F8.0,5X),/,(10X,I2,I3,F2.0,
     1 F8.0,5X,I2,I3,F2.0,F8.0,5X,I2,I3,F2.0,F8.0))
      IF (ICODE-2) 1020,60,1020
   60 IF (SCODE-21.) 1010,70,1010
   65 IF (TOTCAP) 500,500,66
   66 NPROC=1
      CEFF(1)=0.0
      IUNIT(1,1)=IAUX-1
      IUNIT(2,1)=1
      CAP(1)=TOTCAP
   70 DO 150 I=1,NPROC
      DEL=IUNIT(2,I)
      KX=IUNIT(1,I)
   80 DO 100 J=2,10
      IF (CAP(I)-SIZE(KX,J)) 90,110,100
   90 FRAC=(SIZE(KX,J)-CAP(I))/(SIZE(KX,J)-SIZE(KX,J+1))
      GO TO 120
  100 CONTINUE
      CAP(I)=CAP(I)/2.
      DEL=DEL*2.
      GO TO 80
  110 FRAC=1.0
  120 IF (CEFF(I)-EFF(KX,J)) 130,140,140
  130 C1(1)=COST1(KX,J)-(1.0-FRAC)*(COST1(KX,J)-COST1(KX,J-1))+C1(1)
      C1(2)=COST2(KX,J)-(1.0-FRAC)*(COST2(KX,J)-COST2(KX,J-1))+C1(2)
  140 E1(1)=E1(1)+DEFF(KX)*CAP(I)*(1.0-CEFF(I)/100.)
      E1(2)=E1(2)+DEFF(KX)*CAP(I)*(1.0-EFF(KX,J)/100.)
  150 CONTINUE
  160 PRINT 5010, INPUT,C1,E1
 5010 FORMAT(1X,12A4,4E15.0)
      GO TO 20
C
C   CALCULATE ON MODEL PLANT BASIS (1970 305(A))
C
  500 GO TO (510,510,520,530,540) IAUX
  510 C1(1)=139.631
      C1(2)=45.564
      E1(1)=.049749
      E1(2)=.00483
      GO TO 160
  520 C1(1)=82.456
      C1(2)=26.288
      E1(1)=.00451964
      E1(2)=.0004388
      GO TO 160
  530 C1(1)=5.199
      C1(2)=1.682
      E1(1)=.000365753
      E1(2)=.00003551
      GO TO 160
  540 C1(1)=14.464
      C1(2)=5.035
      E1(1)=.10954
      E1(2)=.010635
      GO TO 160
C
C  ERROR ROUTINES
C
 1000 PRINT 5015
 5015 FORMAT(41H ERROR FOUND IN CARD CODE.  "1" EXPECTED.)
      GO TO 20
 1010 PRINT 5020, SCODE
 5020 FORMAT(27H INVALID SOURCE CODE FOUND.,F4.0)
      GO TO 20
 1020 PRINT 5025
 5025 FORMAT(41H ERROR FOUND IN CARD CODE.  "2" EXPECTED.)
      GO TO 20
C
C   END ROUTINE
C
 2000 PRINT 5030
 5030 FORMAT(12H-GOOD FINISH)
      STOP
      END
```

# APPENDIX T

## Computer Program for Sulfuric Acid

# Appendix T

## Computer Program for Sulfuric Acid

## I. INTRODUCTION

The sulfuric acid industry contributes emissions of sulfur dioxide and acid mist particulates to air pollution. Most of the sulfuric acid is produced by the contact process which involves the burning of sulfur or pyrite to form sulfur dioxide which is catalyzed to sulfur trioxide and absorbed in weak acid. This program computes emissions before and after controls assuming a typical plant configuration requiring the installation of a second absorption tower to decrease sulfur dioxide emissions and gas cleaning equipment to lower particulate emissions. A general flow diagram of the computer logic is shown in Figure T-1.

Section II of this report gives the major assumptions made in regard to the calculations of emissions and costs. Section III explains the computer logic and gives tables of input data with formats to enable one to use and/or alter the program. Section IV is a glossary of FORTRAN names. Section V is a listing of the program and the input data which are held constant throughout the program.

## II. ASSUMPTIONS

The assumptions made in regard to the calculations of costs and emissions for the sulfuric acid industry are as follows:

a) Production is 75 percent of capacity.

b) Installed costs in existing plants vary from about 1 to 4 times the cost difference in new construction for control of sulfur dioxide emissions.

c) The basis for cost-of-conversion is the difference in installed costs for single and double absorption for a 1000 ton per day new plant.

d) Capital costs for a converted plant exclude the effect of capacity increase with the assumption that the cost ratio will remain about the same, i.e., increased cost/increased capacity.

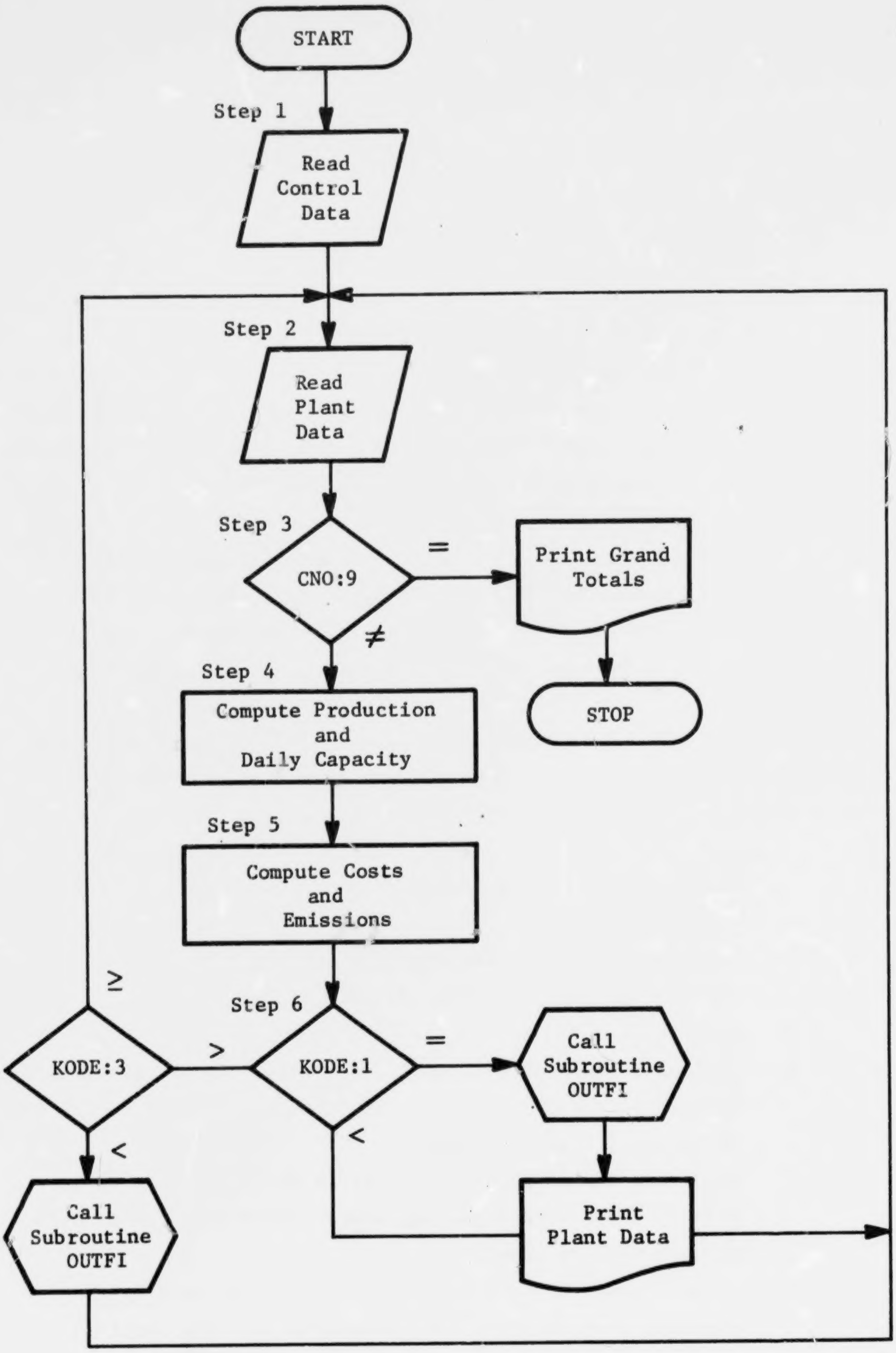

START
Step 1
Read Control Data
Step 2
Read Plant Data
Step 3
CNO:9
=
≠
Print Grand Totals
STOP
Step 4
Compute Production and Daily Capacity
Step 5
Compute Costs and Emissions
Step 6
KODE:1
=
<
>
Call Subroutine OUTFI
Print Plant Data
KODE:3
≥
<
Call Subroutine OUTFI

Fig. T-1. Flow Chart of Program SULFAC

e) To control acid mist particulate emissions, the installation costs in existing plants will vary from 1.5 to 4 times the equipment costs of approximately $43 per thousand acfm flow capacity.

f) Gas flow is equal to about 7.4 thousand acfm per ton per day capacity.

g) Present level of control for particulates is 46 percent and 0 percent for sulfur dioxide.

h) Present control levels are assumed to be the same for all plants.

## III. PROGRAM LOGIC

The plant data available for the sulfuric acid industry consist of plant name, location, and capacity of 100 percent $H_2SO_4$ in thousands of tons per year. If more detailed plant data become available, such as the present controls, etc., modifications to the existing program will be necessary.

Step 1.

The first step in the computer program is to read in the parameters which remain constant throughout the entire program such as KODE and TABLE (I,J) as shown in Table T-1.

Step 2.

This step reads in the plant data on one data card per plant as shown in Table T-2.

Step 3.

In order to effect a printout of grand totals and/or both a printout and the normal termination of the program, extra data cards are inserted. When the program reaches a data card with an "8" or "9" punched in CNO (Column 2), the grand totals for emissions and costs are printed out. If the value for CNO is "8," the totals are zeroed out and the summing process is resumed with subsequent regions until another "8" or "9" appears in the "CNO" column. If the value for CNO is "9," the program is terminated after printing the total costs and emissions.

Step 4.

Production, PROD, is computed in tons per year and capacity, TEMP1, in tons per day as:

PROD = 0.75 TOTCAP x 1000.0;

TEMP1 = (TOTCAP x 1000.0)/365.0.

Step 5.

Subroutine FIND is called in order to return investment and annual costs based on daily capacity, TEMP1, as computed in Step 4.

The emissions of particulates in tons per year before and after controls are computed as:

$$EM1_1 = \frac{9.56\ PROD[1.0-0.46]}{2000.0}, \text{ and}$$

$$EM1_2 = \frac{9.56\ PROD[1.0-0.67]}{2000.0}.$$

The emissions of sulfur dioxide in tons per year before and after controls are computed as follows:

$$EM2_1 = \frac{52.75\ PROD}{2000.0}, \text{ and}$$

$$EM2_2 = \frac{52.75\ PROD[1.0-.86]}{2000.0}.$$

Step 6.

The value of KODE determines when plant data are printed out and when subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

## TABLE T-1. - CONTROL PARAMETERS FOR PROGRAM SULFAC

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Denotes when to bypass subroutine OUTFI and/or to print our plant data. | 1-5 | I5 |
| | Cards 2 thru 9 | | |
| TABLE(I,J), I=1,5, J=1,8 | Investment and annual costs versus plant size, TABLE(1,J) where I is as follows:<br>2 - the investment cost ($1000) for double absorption.<br>3 - the annual cost ($1000) for double absorption.<br>4 - the investment cost ($1000) for mist eliminator.<br>5 - the annual cost ($1000) for mist eliminator. | 1-50 | 5F10.2 |

## TABLE T-2. - PLANT DATA FOR PROGRAM SULFAC

| FORTRAN Name | Description | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| CNO | Card number. | 1-2 | I2 |
| SCODE | Source code number assigned arbitrarily. | 3-5 | I3 |
| RSACQ | National location code. | 6-9 | A4 |
| | Blank | | |
| TOTCAP | Total capacity of plant (100 percent $H_2SO_4$ in thousands of tons/yr.) | 11-20 | F10.0 |
| | Blank | 21-30 | 10X |
| INP(I) | Name and location of plant. | 31-78 | 12A4 |

# IV. GLOSSARY OF FORTRAN NAMES FOR PROGRAM SULFAC

| FORTRAN Name | Definition |
|---|---|
| ANS(20) | Table lookup values returned from subroutine FIND. |
| CNO | Card number and/or type. |
| COST(2) | Investment and annual operating cost for each plant. |
| COSTIN | Sum of investment costs for all plants. |
| COSTYR | Sum of annual costs for all plants. |
| EM1(2) | Emissions of particulates before and after controls. |
| EM2(2) | Emission of sulfur dioxide before and after controls. |
| IC | Dummy calling parameter for subroutine OUTFI. |
| IN | The I-th column of TABLE(I,J) from which the first ANS(I) is to be returned. |
| INC | The incremental value of I for which ANS(I) is returned from TABLE(I,J). |
| INP(12) | Variables containing the name and location of each plant. |
| JNE1 | Numerical value arbitrarily assigned to the first emission data being passed to subroutine OUTFI. |
| JNE2 | Numerical value arbitrarily assigned to the second emission data being passed to subroutine OUTFI. |
| LIM | Number of columns in TABLE(I,J). |
| MAX | Number of rows in TABLE(I,J). |

Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| NE | Total number of emission types being passed to Subroutine OUTFI. |
| PROD | Production of 100 percent $H_2SO_4$ in tons per year. |
| RSAC | National location code. |
| SCODE | Number arbitrarily assigned to source. |
| SUM1 | Sum of particulate emissions before controls. |
| SUM2 | Sum of particulate emissions after controls. |
| SUM3 | Sum of sulfur dioxide emissions before controls. |
| SUM4 | Sum of sulfur dioxide emissions after controls. |
| TABLE(20,20) | Matrix for storing tabulated values of data for subroutine FIND. |
| TEMP1 | Capacity in tons per day used as basis for investment and annual operating costs from TABLE(I,J). |
| TOTCAP | Input variable containing plant capacity of 100 percent $H_2SO_4$ (1000 tons/year). |

## V. LISTING OF THE COMPUTER PROGRAM FOR SULFURIC ACID

```
C     PROGRAM SULFAC
C        PROGRAM TO COMPUTE CONTROL OF EMISSIONS INHERENT TO THE
C           SULFURIC ACID INDUSTRY. POLLUTANT EMISSIONS ARE SULFUR
C           DIOXIDE AND ACID MIST PARTICULATES.
      INTEGER CNO,SCODE,RSAC
      DIMENSION INP(12),TABLE(20,20),EM1(2),EM2(2),COST(2),ANS(20)
      READ 490, KODE
 490  FORMAT (I5)
C        READ IN TABLE OF PLANT SIZE VS COSTS ($1000) FOR DOUBLE
C           ABSORPTION AND MIST ELIMINATOR.  TABLE(I,J) WHERE
C              I =1 FOR SIZE
C              I =2 FOR INVESTMENT COST ($1000) FOR DOUBLE ABSORPTION
C              I =3 FOR ANNUAL COSTS ($1000) FOR DOUBLE ABSORPTION
C              I =4 FOR INV. COSTS ($1000) FOR  MIST ELIM. (PARTICULATE)
C              I =5 FOR ANNUAL COSTS ($1000) FOR MIST ELIM.(PARTICULATE)
C           AND J VARIES FROM 1 TO 8 FOR THE J-TH PLANT SIZE.
      READ 600,((TABLE(I,J),I=1,5),J=1,8)
 600  FORMAT (5F10.2)
      IC = 0
      L = 0
      NE = 2
      JNE1 = 1
      JNE2 = 2
      IN= 2
      LIM = 5
      MAX = 8
      INC = 1
 6    SUM1 = 0.
      SUM2 = 0.
      SUM3 = 0.
      SUM4 = 0.
      COSTIN = 0
      COSTYR = 0.
C        CAPACITY IS 100% H2SO4 (1000 TONS/YR)
 8    CONTINUE
      READ 500, CNO,SCODE,RSAC,TOTCAP,(INP(I),I=1,12)
 500  FORMAT (I2,I3,A4,1X,F10.0,10X,12A4)
      IF(CNO-8)10,800,800
 10   CONTINUE
C     PROD IS IN TONS/YR.
C      TEMP1 IS IN TONS/DAY
      PROD = 0.75 * TOTCAP * 1000.0
      TEMP1 = (TOTCAP * 1000.0)/365.0
      SCODE =  10
      CALL FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
C
C         SUBROUTINE FIND RETURNS THE INVESTMENT AND ANNUAL COSTS FOR
C            EACH INDUSTRY.
C
      COST(1) = ANS(2) + ANS(4)
      COST(2) = ANS(3) + ANS(5)
 70   CONTINUE
      EM1(1) =(PROD * 9.56 * (1.0 - 0.45))/2000.
      EM1(2) =(PROD * 9.56 * (1.0 - 0.67) )/2000.
      EM2(1) =(PROD * 52.75   )/2000.0
      EM2(2) =(PROD * 52.75    * (1.0 - .86))/2000.0
      IF(KODE-1)200,210,220
  200 CONTINUE
C         PRINT PLANT DATA
      PRINT 550, (INP(I),I= 1,12),EM1(1),EM1(2),EM2(1),EM2(2),COST(1),
     2COST(2)
      GO TO 8
  210 CONTINUE
C         PRINT PLANT DATA
      PRINT 550, (INP(I),I= 1,12),EM1(1),EM1(2),EM2(1),EM2(2),COST(1),
     2COST(2)
  220 CONTINUE
      IF(KODE - 3)230,250,250
  230 CONTINUE
      CALL OUTFI(RSAC,IC,L,SCODE,INP,COST ,NE,JNE1,EM1,JNE2,EM2)
  250 CONTINUE
      COSTIN = COSTIN + COST(1)
      COSTYR = COSTYR + COST(2)
      SUM1 = SUM1 + EM1(1)
      SUM2 = SUM2 + EM1(2)
      SUM3 = SUM3 + EM2(1)
      SUM4 = SUM4 + EM2(2)
      GO TO 8
  800 CONTINUE
      PRINT 560, SUM1,SUM2,SUM3,SUM4,COSTIN,COSTYR
      IF(CNO-8)8,6,820
  820 CONTINUE
  550 FORMAT (2X,12A4,6F11.2)
  560 FORMAT(48X,6F12.0,//)
      STOP
      END
      SOURCE LIST
      SUBROUTINE FIND(TEMP1,TABLE,LIM,MAX,IN,INC,ANS)
C          THE PURPOSE OF THE SUBROUTINE IS TO DO A TABLE LOOKUP
C            FOR ANY TABLE(I,J) BASED ON THE FOLLOWING
C                 I = 1,LIM
C                 J = 1,MAX
C                 TEMP1 IS THE PARAMETER FOR WHICH VALUES ARE FOUND
C                 ANS(I) IS THE INTERPOLATED VALUE FOR TEMP1
C                 IN IS THE BEGINNING OF I
C                 INC IS THE INCREMENT OF I
      DIMENSION TABLE(20,20),ANS(20)
      IF (TEMP1-TABLE(1,1))5,5,6
    5 CONTINUE
      DO 4 I = IN,LIM,INC
    4 ANS(I) = TABLE(I,1)
      GO TO 60
    6 CONTINUE
      IF(TEMP1-TABLE(1,MAX))9,9,8
    8 PRINT 100
  100 FORMAT(48H PLANT SIZE IS LARGER THAN MAXIMUM SIZE IN TABLE,//)
      DO 7 I = IN,LIM,INC
    7 ANS(I) = TABLE(I,MAX)
      GO TO 60
    9 CONTINUE
      DO 30 J = 1,MAX
      IF (TEMP1-TABLE(1,J))10,20,30
```

```
 10 RATIO = (TEMP1-TABLE(1,J-1)) /(TABLE(1,J) - TABLE(1,J-1))
    JJ = J
    GO TO 40
 20 RATIO = 1.0
    JJ = J
    GO TO 40
 30 CONTINUE
 40 DO 50 I = IN,LIM,INC
 50 ANS(I) = RATIO *(TABLE(I,JJ)-TABLE(I,JJ-1)) + TABLE(I,JJ-1)
60    CONTINUE
    RETURN
    END
```

```
INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS:


  0
    0.          0.          0.          0           0.
   25.00      104.00       24.00        2.0         0.4
   50.00      187.00       40.00        4.50         .90
  100.00      284.00       61.00        9.50        1.90
  200.00      429.00       94.00       19.50        3.90
  500.00      745.00      165.00       43.80        8.80
 1000.00     1165.00      271.00       82.50       16.50
 5000.00     3277.00      815.00      375.00       75.00
```

# APPENDIX U

## Computer Program for Varnish

# Appendix U

## Computer Program for Varnish

### I. INTRODUCTION

The production of varnish results in the emission of hydrocarbons. The purpose of this appendix is to describe a computer program designed to compute the emissions both before and after controls and the investment and annual operating costs for controlling the emissions. The data for the computations were taken from the Dun and Bradstreet Middle Market Directory 1970. Plant data consist of name and location of plant, and an estimate of the number of employees engaged in the manufacture of varnish. These are not ideal data but are sufficient to permit a plant by plant evaluation as will be described in this appendix. A general flow diagram of the computer logic is shown in Figure U-1.

Section II of this report gives the major assumptions in the computer program. Section III explains the program logic and gives tables of input data with formats to enable one to use and/or alter the program. Section IV contains a glossary of FORTRAN names for the program and Section V is a listing of the computer program for the industry.

### II. ASSUMPTIONS

The major assumptions made in regard to the calculations of emissions and costs for the computer program are as follows:

a) Annual plant capacities are based on 30.5 gallons of varnish per day per employee and 240 days of operation per year.

b) Annual control costs are based on 2400 hours of operation per year.

c) Control costs are based on use of direct fixed afterburners without heat exchange.

d) Annualized costs take into account three variations in afterburner gas fuel costs throughout the country.

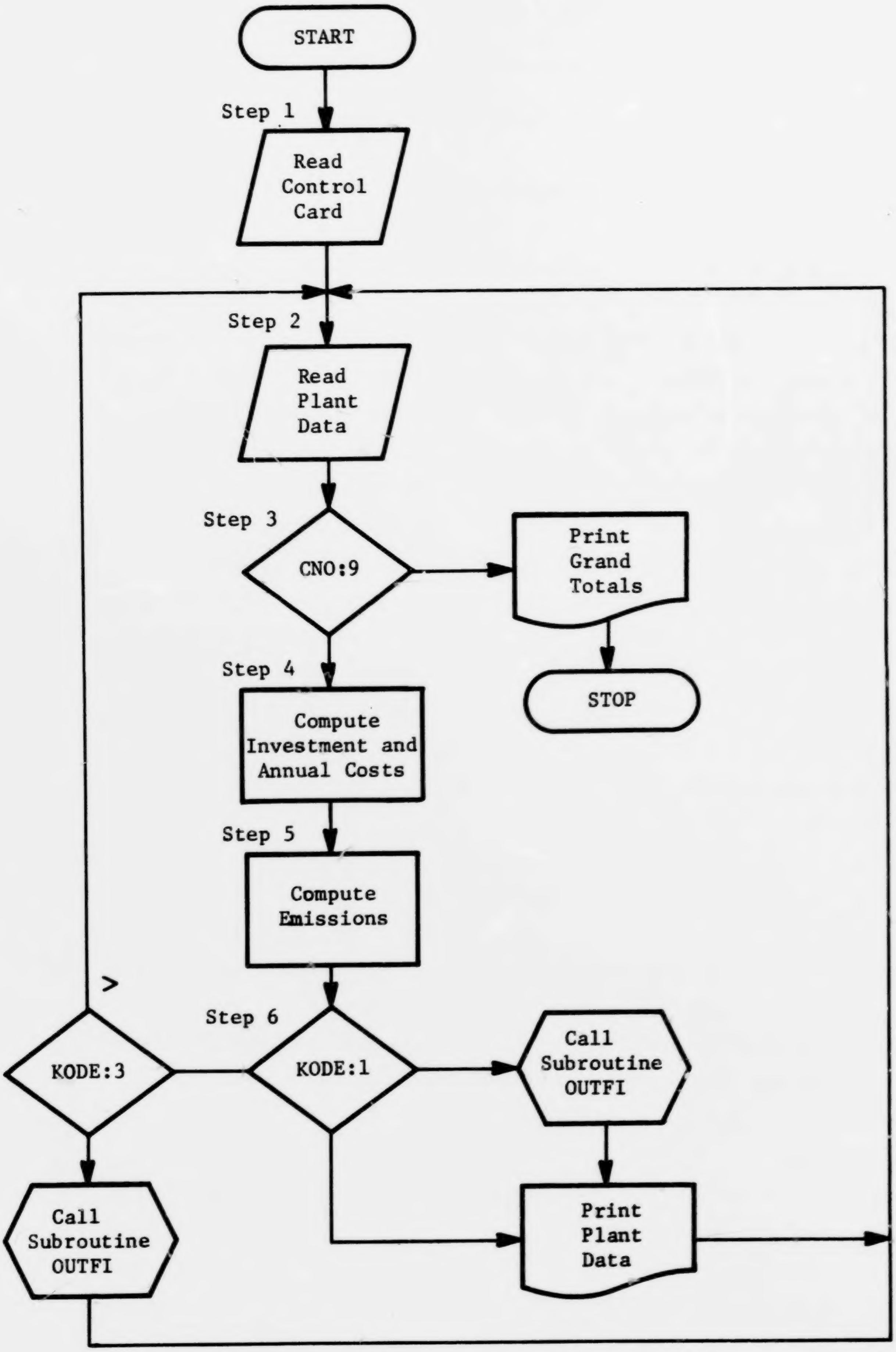

START
Step 1
Read Control Card
Step 2
Read Plant Data
Step 3
CNO:9
Print Grand Totals
STOP
Step 4
Compute Investment and Annual Costs
Step 5
Compute Emissions
>
Step 6
KODE:3
KODE:1
Call Subroutine OUTFI
Call Subroutine OUTFI
Print Plant Data

Fig. U-1. Flow Chart for Program VARN

## III. PROGRAM LOGIC

The FORTRAN names for the emissions of hydrocarbons from the varnish industry are EM1 for present emissions, and EM2 for controlled emissions. The investment and operating costs for each installation are COST1(1) and COST1(2), respectively.

Step 1.

Step 1 consists of reading in one datum which controls the output of individual plant data and the calling of subroutine OUTFI, as explained in Step 6. Table U-1 shows the format of this parameter.

Step 2.

The input data with formats and definitions for each plant are input on card 2 as shown in Table U-1.

Step 3.

A data card is inserted at the end of the plant data with a "9" punched in Column 2 in order to effect a normal program termination. This datum point is input as "CNO" of the plant data, and is checked each time a plant is processed. When "CNO" is equal to "9," the grand totals are printed and the program is terminated.

Step 4.

The annualized costs for controlling emissions are very much dependent on the capacity and location of the plant. Table U-2 shows the annualized cost factors (including 20 percent depreciation and capital changes) for different parts of the country as a function of two plant sizes. These cost factors are built into the program. Each plant is designated a geographical region according to the code, IREG. The capital and annual costs ($1000) are then computed as follows:

$$\text{COST1(1)} = \frac{\text{122TOTPOP} + 2000.0}{1000.} ,$$

$$\text{COST1(2)} = \frac{\text{22.2TOTPOP} + 400 + \text{CFAC}}{1000.} .$$

CFAC is determined by IREG and plant capacity as shown in Table U-2.

Step 5.

The annual emissions in tons are computed as:

$$EM1(1) = \frac{0.91\ TOTPOP}{2000.}\ , \text{ and}$$

$$EM1(2) = \frac{0.1106\ TOTPOP}{2000.}\ .$$

Running sums of the costs and emissions are kept in order to output grand totals at the end of the program.

Step 6.

The value of KODE determines when plant data are printed out and when subroutine OUTFI is called as follows:

| KODE | Print Plant Data | Call OUTFI |
|---|---|---|
| 0 | yes | no |
| 1 | yes | yes |
| 2 | no | yes |
| 3 | no | no |

Subroutine OUTFI, which outputs data in the form of punched cards for the master program, is explained in Appendix V.

TABLE U-1. - INPUT DATA FOR PROGRAM VARN

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| KODE | Denotes when to print plant data and/or when to bypass Subroutine OUTFI. | 1-5 | I5 |
| | Card 2 | | |
| CNO | Card number and type. | 1-2 | I2 |
| SCODE | Source code number assigned arbitrarily. | 3-5 | I3 |
| RSAC | National location code. | 6-9 | A4 |
| | Blank. | 10 | 1X |
| TOTCAP | Number of employees in plant engaged in manufacture of varnish. | 11-20 | F10.2 |
| | Blank. | 21-22 | 2X |
| NPLT | Plant number. | 23-26 | I4 |
| IREG | Code to denote geographical region of plant. | 27-30 | I4 |
| INP | Name and location of plant. | 31-78 | 12A4 |

TABLE U-2. - CAPACITY VERSUS ANNUALIZED COST FACTORS

| Plant Capacity (gal) | Annualized Cost Factors ($) | | |
|---|---|---|---|
| | East Coast, Northwest, and Hawaii | Midwest | Southwest and Gulf Coast |
| | IREG=1 | IREG=2 | IREG=3 |
| 0 to 250 | 4390 | 2650 | 1820 |
| 250 to 1000 | 8705 | 5225 | 3365 |

## IV. GLOSSARY OF FORTRAN NAMES FOR PROGRAM VARN

| FORTRAN Name | Definition |
|---|---|
| CAP | Plant capacity in gallons per day. |
| CFAC1 | Cost factor for plant smaller than or equal to 275 gallons per day. |
| CFAC2 | Cost factor per plant larger than 275 gallons per day. |
| CNO | Card number and type in plant data. |
| COST1(2) | Installation and annualized costs ($1000). |
| EM1(2) | Controlled and uncontrolled hydrocarbon emissions (tons/yr.). |
| INP(12) | Name and location of plant. |
| IREG | Code in type 1 plant data card to denote geographical region of plant. |
| JNE | Numerical value assigned to hydrocarbon emissions (3) for use in subroutine OUTFI. |
| KODE | Input value to determine when to bypass subroutine OUTFI and/or the output of plant data. |
| NE | The total number of pollutants from the source. |
| NPLT | Number assigned to plant. |
| RSAC | National location code. |
| SCODE | Source code number assigned arbitrarily. |
| SUM1 | Sum of EM1(1) for output of grand totals. |
| SUM2 | Sum of EM1(2) for output of grand totals. |
| SUM3 | Sum of COST1(1) for output of grand totals. |

## Glossary of FORTRAN Names (continued)

| FORTRAN Name | Definition |
|---|---|
| SUM4 | Sum of COST1(2) for output of grand totals. |
| TOTCAP | Number of employees engaged in manufacture of varnish. |
| TOTPOP | Same as TOTCAP. |

## V. LISTING OF THE COMPUTER PROGRAM FOR VARNISH

```
C       PROGRAM VARN
C          THE PURPOSE OF THIS PROGRAM IS TO COMPUTE THE EMISSIONS AND
C       COSTS FOR CONTROLLING EMISSIONS IN THE VARNISH INDUSTRY BASED ON
C       PRESENT DATA
C          INPUT DATA CONSISTS OF THE FOLLOWING
C               CNO - CARD NO.
C               SCODE - SOURCE CODE NO.
C               RSAC - REGION,STATE,AREA,COUNTY CODE
C               TOTCAP - TOTAL CAPACITY IS NO. EMPLOYEES/PLANT
C               NPLT - PLANT NO -USED FOR IDENTIFICATION PURPOSES
C               IREG - DESIGNATES GEOGRAPHICAL REGION AS FOLLOWS
C                 1 FOR EAST COAST, NORTHWEST, AND HAWAII.
C                 2 FOR MIDWEST
C                 3 FOR SOUTHWEST AND GULF COAST.
C          OUTPUT DATA CONSISTS OF EMISSIONS (TONS) OF HYDROCARBONS BEFORE
C            AND AFTER CONTROLS, AND COSTS OF CONTROLS.
C
        INTEGER CNO,SCODE,RSAC
        DIMENSION INP(12),COST1(2),EM1(2)
C          READ IN KODE TO DETERMINE THE FOLLOWING0
C           KODE VALUE  PLANT DATA  CALL OUTFI
C           --------  ------------  ----------
C               0           YES             NO
C               1           YES             YES
C               2           NO              YES
C               3           NO              NO
        READ 610, KODE
  610   FORMAT (I5)
        NE = 1
        ONE = 3
        PRINT 590
  590   FORMAT (50H PLANT NO.    EM1          EM2        COST1       COST2    )
   1    CONTINUE
        READ 500, CNO,SCODE, RSAC, TOTCAP,NPLT,IREG,(INP(I),I=1,12)
  500   FORMAT (I2,I3,A4,X, F10.2,2X,I4,I4, 12A4)
        TOTPOP = TOTCAP
        IF(CNO-9) 10,100,10
  10    CONTINUE
        IF(IREG-2)12,14,16
  12    CFAC1 = 3152.0
        CFAC2 = 7304.0
        GO TO 18
  14    CFAC1 = 1792.0
        CFAC2 = 3594.0
        GO TO 18
  16    CFAC1 = 1052.0
        CFAC2 = 2104.0
  18    CONTINUE
C          COMPUTE ANNUAL AND INSTALLATION COSTS IN $1000 DOLLARS FOR
C            EACH PLANT
        CAP = TOTPOP* 30.5
        COST1(1) =(122.0*TOTPOP+2000.0)/ 1000.0
        IF(CAP-275.0)20,20,30
```

```
 20    COST1(2) = (22.2 * TOTPOP +400.0 + CFAC1)/1000.0
       GO TO 60
 30    COST1(2) = (22.2 * TOTPOP +400.0 + CFAC2)/1000.0
       IF(CAP-1000.)60,60,50
 50    COST1(2) = (CAP/1000.) * COST1(2)
 60    CONTINUE
C         COMPUTE ANNUAL EMISSIONS IN TONS
C              EM1(1) - 1967 EMISSIONS
C              EM1(2) - CONTROLLED EMISSIONS
       EM1(1) =(0.91 * TOTPOP) /2000.0
       EM1(2) =(0.1106*TOTPOP) /2000.0
       SUM1 = SUM1 + EM1(1)
       SUM2 = SUM2 + EM1(2)
       SUM3 = SUM3 + COST1(1)
       SUM4 = SUM4 + COST1(2)
       IF(KODE-1)200,210,220
 200   CONTINUE
C         PRINT PLANT DATA.
       PRINT 600, NPLT,(INP(I),I=1,12),EM1(1),EM1(2),COST1(1),COST1(2)
       GO TO 1
 210   CONTINUE
       PRINT 600, NPLT,(INP(I),I=1,12),EM1(1),EM1(2),COST1(1),COST1(2)
       IF(KODE - 3)220,250,250
 220   CONTINUE
       CALL OUTFI (RSAC, 0,0,SCODE,     INP,COST1,NE,JNE,EM1)
 250   CONTINUE
       GO TO 1
 100   CONTINUE
       PRINT 900, SUM1,SUM2,SUM3,SUM4
 600   FORMAT (2X,I5,12A4,4F10.3)
 900   FORMAT (1H0,10X,4F10.3)
       STOP
       END
```

INPUT PARAMETERS WHICH REMAIN CONSTANT ARE LISTED AS FOLLOWS:

0

# APPENDIX V

## Source Output Subroutine (OUTFI)

# Appendix V

## Source Output Subroutine (OUTFI)

### I. INTRODUCTION

Subroutine OUTFI provides standard card output for each plant processed by each source program (Subroutine OUTFI appears in each source program). The data punched by this subroutine are later combined with other source results and used to prepare output summaries, growth estimates, and implementation schedules.

### II. SUBROUTINE OPERATION

This subroutine does not do any actual calculation but simply passes data from the program to card output. Since up to four emissions may be present in any specific source and the cost to control all of these emissions is done on a plant basis, this subroutine punches a separate card for each emission but puts cost data only on the first card of the set for a plant. Aside from the omission of cost data, each card has the same format.

### III. INPUT VARIABLES

Table V-1 shows the input variables and terms used by OUTFI. Since many sources do not have four pollutants, the variables not needed are omitted from the call of this subroutine and the number of pollutants code NE is used to determine how many cards are produced for each plant. For NE=1, only one card is punched, for NE=2, two cards are punched, for NE=3, three cards are punched, and for NE=4, four cards are punched for each plant.

TABLE V-1. - VARIABLES CALLED BY AND USED IN SUBROUTINE OUTFI

| FORTRAN Name | Definition |
|---|---|
| NR1 | RSAC Number (A4)* |
| NR2 | RSAC Part Code (A1) (usually blank) |
| NAQR | Metropolitan Area Number (A3)* |
| NS | Source Number (I2)* |
| NAME(12) | Plant Name (6A4) |
| CO(2) | Control Costs (2F11.2) (in thousands of dollars) |
| NE | Number of Pollutants (Integer number 1-4) |
| JE1 | Pollutant Code* for first pollutant |
| EM1(2) | Emissions before and after control for pollutant one. |
| JE2 | Pollutant Code* for second pollutant |
| EM2(2) | Emission before and after control for pollutant two. |
| JE3 | Pollutant Code* for third pollutant |
| EM3(2) | Emission before and after control for pollutant three. |
| JE4 | Pollutant Code* for fourth pollutant |
| EM4(2) | Emission before and after control for pollutant four. |

---

* RSAC numbers, metropolitan area numbers, source numbers, and pollutant numbers are described in Appendix W.

## IV. OUTPUT

Table V-2 shows the columns locations and format for the punched cards. When more than one card per plant is specified, the second, etc., cards contain blanks in columns 13-34 instead of cost data. These cards are used directly by programs MATCH, FILE, or SEARCH as described in Appendix W.

TABLE V-2. - DATA CONTAINED ON SOURCE OUTPUT CARDS (SUBROUTINE OUTFI)

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| | Blank | 1 | IX |
| NR1 | RSAC code | 2-5 | A4 |
| NR2 | RSAC divisor (usually blank) | 6 | A1 |
| NS | Source code | 7-8 | I2 |
| NE1 | Pollutant code | 9 | I1 |
| NAQR | Metropolitan area | 10-12 | A3 |
| CO(1) | Investment costs (thousands) | 13-23 | F11.2 |
| CO(2) | Annual costs (thousands) | 24-34 | F11.2 |
| EM1(1) | Present emissions (tons/yr.) | 35-45 | F11.2 |
| EM1(2) | Controlled emissions (tons/yr.) | 46-56 | F11.2 |
| NAME(12) | Plant name, etc. | 57-80 | 6A4 |
| | Card 2 | | |
| | Card columns 13-34 are blank because cost is not applicable. JE2 and EM2 are substituted for JE1 and EM1 respectively; otherwise the same as Card 1. | | |
| | Card 3 | | |
| | JE3 and EM3 are substituted for JE1 and EM1 respectively; otherwise the same as Card 2. | | |
| | Card 4 | | |
| | JE4 and EM4 are substituted for JE1 and EM1 respectively; otherwise the same as Card 2. | | |

# V. LISTING OF SOURCE OUTPUT SUBROUTINE OUTFI

```
      SUBROUTINE OUTFI (NR1,NR2,NAQCR,NS,NAME,CO,NE,JE1,EM1,JE2,EM2,
                                                   JE3,EM3,JE4,EM4)
C
C     SUBROUTINE TO PUNCH CARDS FROM SOURCE SUBROUTINES
C
C              EACH CARD HAS IDENT AND EMISSIONS
C              ONLY FIRST CARD HAS COST DATA
C              UP TO FOUR POLLUTANTS FOR A PARTICULAR SOURCE
C
C     SETUP TO PUNCH ONLY PRESENT COSTS AND EMISSIONS
C
      DIMENSION NAME(12),CO(2),EM1(2),EM2(2),EM3(2),EM4(2)
      WRITE(10,101) NR1,NR2,NS,JE1,NAQCR,(CO(I),I=1,2),(EM1(I),I*1,2),
     1 (NAME(I),I=1,6)
  101 FORMAT(1X,A4,A1,I2,I1,A3,4F11.2,6A4)
      IF(NE-1) 5,5,2
    2 WRITE(10,102) NR1,NR2,NS,JE2,NAQCR,(EM2(I),I=1;2),(NAME(I),I=1,6)
  102 FORMAT(1X,A4,A1,I2,I1,A3,22X,2F11.2,6A4)
      IF(NE-2) 5,5,3
    3 WRITE(10,102) NR1,NR2,NS,JE3,NAQCR,(EM3(I),I=1;2),(NAME(I),I=1,6)
      IF(NE-3) 5,5,4
    4 WRITE(10,102) NR1,NR2,NS,JE4,NAQCR,(EM4(I),I=1;2),(NAME(I),I=1,6)
    5 CONTINUE
      RETURN
      END
```

```
***  OUTPUT DATA  ***


 1111  71        140.04      91.18     546.16      179.23CARPENTER STEEL BRIDGEPO
 1111  75                               43.57       26.64CARPENTER STEEL BRIDGEPO
 1561  71        287.02     186.86    1006.49      308.87C F AND I STEEL CORP ROE
 1561  75                               80.29       47.65C F AND I STEEL CORP ROE
 1611  71        343.99     223.96    1076.71      422.48ALLEGHENY LUDLUM STEEL D
 1611  75                               85.89       57.21ALLEGHENY LUDLUM STEEL D
 1631  71      25823.50   14124.03   18500.19     1237.45BETHLEHEM STEEL CORP LAC
 1631  71       8494.81    3485.38    6585.78      510.61REPUBLIC STEEL CORP BUFF
 1631  71       1481.67    1222.86    8766.31      312.07ERIE COUNTY, NY
 1631  75                             1021.56       19.31BETHLEHEM STEEL CORP LAC
 16R4  71         50.49      32.87     156.04       66.09WICKWIRE BROTHERS CORTLA
 16R4  75                               12.45        8.62WICKWIRE BROTHERS CORTLA
```

# APPENDIX W

## File and Report Programs

# Appendix W

## File and Report Programs

## I. INTRODUCTION

All output data from the various source programs, through Subroutine OUTFI, must at one time be matched to its corresponding metropolitan area (AQCR), kept on a master file, and displayed as a summary. This appendix is broken down into five sections: Section I, Introduction; Section II, Data Uniformity Processor; Section III, File Maintenance; Section IV, Report Generator Programs; and Section V, Listing of Source, Pollutant, and Location Codes.

The report generator programs allow both data from a particular source to be simply displayed or summations of results can be displayed by metropolitan area, etc. In general it is best to process the data through both the data uniformity processor and insert this data into the master file so as to have available the results by metropolitan area, state, aggregate metropolitan area, and/or nationwide.

## II. DATA UNIFORMITY PROCESSOR

### A. Introduction

The data processor program MATCH makes sure that each data card contains both an RSAC and metropolitan area code for use by later programs. A listing of this matching data file is given in Section V. Program MATCH supplies the metropolitan area code to plant data that is identified only by the RSAC county code and alternatively provides a state RSAC code if the particular source data is located only by a metropolitan area code. The general flow chart for this program is shown in Figure W-1.

### B. Control Card Input

Table W-1 shows the layout of the control cards used in program MATCH. Columns 2, 8, 9, and 10 are used to compare specific groups of alphanumeric data on the master data file. Column one indicates the "end-of-run" alphanumeric indicator and although a nine is usually

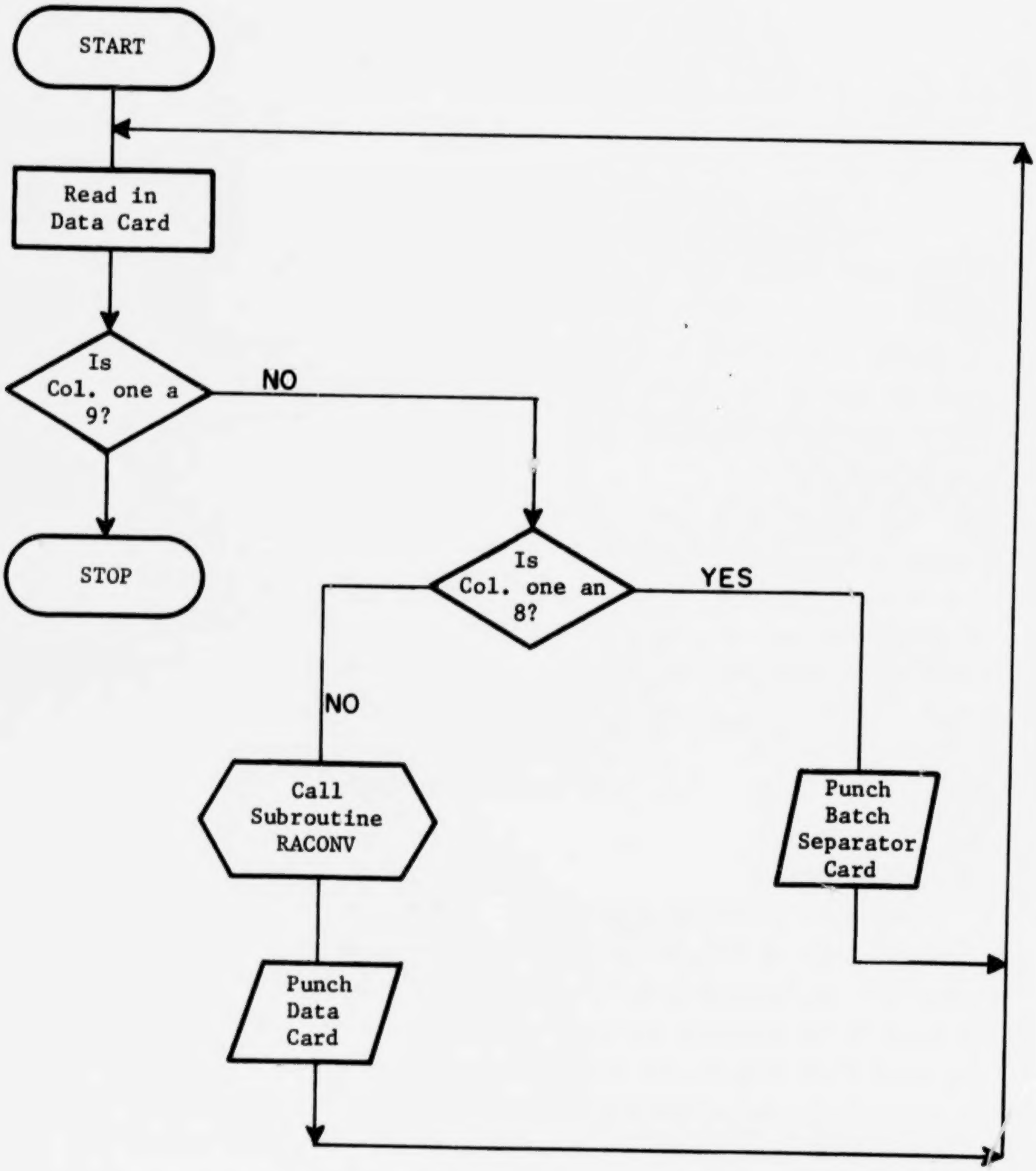

START
Read in Data Card
Is Col. one a 9?
NO
STOP
Is Col. one an 8?
YES
NO
Call Subroutine RACONV
Punch Batch Separator Card
Punch Data Card

Fig. W-1.– General Flow Chart of Program MATCH.

used, any valid alphanumeric can be used as long as the same code is used in the "last-of-run" card. The last of group indicator (usually 8) is also restricted but only in this way.

The reject metropolitan area is simply the metropolitan area to be used when no match is found and due to restrictions by later programs, it can be no greater than 305.

TABLE W-1. - CONTROL CARDS FOR PROGRAM MATCH

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Process Control Card | | |
| ININE* | Last card of run indicator. | 1 | A1 |
| IBL | Blank (used by program). | 2 | A1 |
| I305(I)*<br>I=1,3 | Reject AQCR (305 max.). | 3-5 | 3A1 |
| IEIGHT* | Last card in group indicator. | 6 | A1 |
| IPRINT* | Print control (=1, print each card). | 7 | I1 |
| IZER1 | Alphanumeric zero. | 8 | A1 |
| IZER2 | Two alphanumeric zeros. | 9-10 | A2 |
| | Last Card in Group of Data | | |
| ICTO* | Last card in data (ININE) | 1 | A1 |

* Entries that should not be zero or blank.

All mis-matches are printed. However, it is sometimes desirable to print all cards after receiving a metropolitan area number and putting a one (1) into column 7 will key the program to print all processed cards.

If only one batch of cards is being matched (do not need to be separated), the end of group card need not be included although the code on the first card cannot be blank.

## C. Data Input and Output

Table W-2 shows the layout of both the input and output cards from MATCH. Except for either the RSAC or metropolitan area code missing on the input card, there is no difference between the data or form of the input and output cards. The data contained on the cards are: (1) RSAC code, (2) RSAC devisor code (see Section V), (3) source code, (4) pollutant code, (5) metropolitan area, (6) 1967 investment and annual costs for control equipment (thousands of dollars), (7) uncontrolled and controlled emission rates (tons/year), and (8) twenty-four characters of alphanumeric data identifying the source, plant, or location.

All metropolitan area codes, source codes, and pollutant codes are listed in Section V.

## D. Program Operation

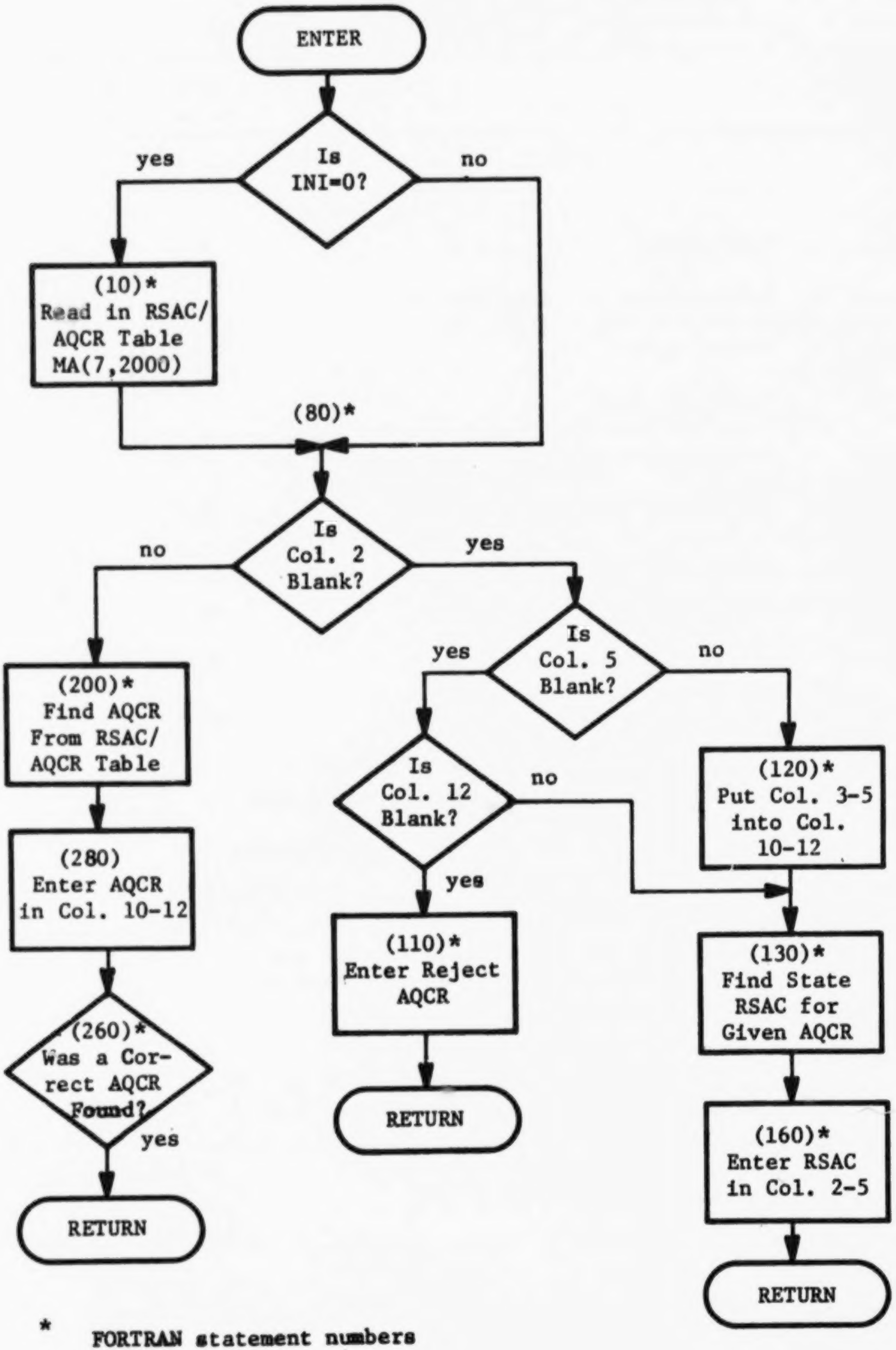
As shown in Figure W-1, the main program basically determines only if an 8 or 9 code appears in column one; if so, the program punches a deck separator card or terminates the program, respectively. If column one contains neither an 8 nor 9, the card is assumed to be a data card, the matching metropolitan area or RSAC is determined by Subroutine RACONV, and the card punched. All matching of RSAC and AQCR is done in Subroutine RACONV and the indicator INI is used to key Subroutine RACONV to read to the AQCR/RSAC matching file from tape (INI=0) or to use the matching table already in memory (INI=1).

A general flow chart of Subroutine RACONV is shown in Figure W-2. RACONV checks columns 2, 5, and 12 for data entry (RSAC in Column 2-5, AQCR in Column 3-5, or AQCR in 10-12). If blanks are found in all of these locations, the reject AQCR (specified by an input card) is entered in columns 10-12 and control is returned to the main program. If column 2 is not blank, RACONV searches the RSAC/AQCR file for a match to the specified RSAC. If a valid entry is found (either a complete match or a match with an RSAC state code where the AQCR encompasses the entire state) this match is entered into columns 10-12 and control returns to the main program.

If column 2 is blank but columns 3-5 or 10-12 contain a valid AQCR, a match between this code and the corresponding state code

TABLE W-2. - DATA CONTAINED ON SOURCE OUTPUT CARDS (Subroutine OUTFI)

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| | Blank. | 1 | 1X |
| NR1 | RSAC code. | 2-5 | A4 |
| NR2 | RSAC divisor (usually blank). | 6 | A1 |
| NS | Source code. | 7-8 | I2 |
| JE1 | Pollutant code | 9 | I1 |
| NAQR | Metropolitan area code. | 10-12 | A3 |
| CO(1) | Investment costs (thousands). | 13-23 | F11.2 |
| CO(2) | Annual costs (thousands). | 24-34 | F11.2 |
| EM1(1) | Present emissions (tons/yr.). | 35-45 | F11.2 |
| EM1(2) | Controlled emissions (tons/yr.). | 46-56 | F11.2 |
| NAME(12) | Plant name, etc. | 57-80 | 6A4 |
| | Card 2 | | |
| | Card columns 13-34 are blank because cost is not applicable. JE2 and EM2 are substituted for JE1 and EM1, respectively; otherwise the same as Card 1. | | |
| | Card 3 | | |
| | JE3 and EM3 are substituted for JE1 and EM1, respectively; otherwise the same as Card 2. | | |
| | Card 4 | | |
| | JE4 and EM4 are substituted for JE1 and EM1, respectively; otherwise the same as Card 2. | | |


ENTER
Is INI=0?
yes
no
(10)* Read in RSAC/ AQCR Table MA(7,2000)
(80)*
Is Col. 2 Blank?
no
yes
(200)* Find AQCR From RSAC/ AQCR Table
(280) Enter AQCR in Col. 10-12
(260)* Was a Correct AQCR Found?
yes
RETURN
Is Col. 5 Blank?
yes
no
Is Col. 12 Blank?
no
yes
(110)* Enter Reject AQCR
RETURN
(120)* Put Col. 3-5 into Col. 10-12
(130)* Find State RSAC for Given AQCR
(160)* Enter RSAC in Col. 2-5
RETURN

* FORTRAN statement numbers

Fig. W-2. Overall Flow Chart of Subroutine RACONV.

(see Section V) is found and this state RSAC code is entered into columns 2-5 with the AQCR in columns 10-12. Control then returns to the main program.

### E. Glossary of FORTRAN Names for Data Uniformity Program (MATCH)

| FORTRAN Name | Definition |
|---|---|
| | Program MATCH |
| DAT(4) | Temporary data storage location. |
| I305(3) | Reject AQCR number (usually 305) (3A1). |
| IBL | Alphanumeric blank (A1). |
| ICTO | Control input variable (end of batch, etc.). |
| IEIGHT | End of group indicator (usually an 8). |
| INI | Match table read control (=0 read table, =1 if table already read). |
| ININE | End of run indicator (usually a 9). |
| IPRINT | Print control (≠0, print each card). |
| IZER1 | Alphanumeric zero (A1). |
| IZER2 | Alphanumeric zero (A2). |
| NAME(6) | Temporary storage of location data (6A4). |
| NQ(3) | AQCR storage (3A1). |
| NR(4) | RSAC storage (4A1). |
| NS | Source and pollutant storage (A3). |
| | Subroutine RACONV |
| I305(3) | Reject AQCR number (usually 305) (3A1). |
| IBL | Alphanumeric blank. |
| IBLK | Alphanumeric blank. |

| | |
|---|---|
| ICOUNT | Match table input record counter. |
| INI | Initializing control (≠0, table read). |
| IREG | Number of AQCR regions (set at 298). |
| IZER1 | Alphanumeric zero (A1). |
| IZER2 | Alphanumeric zero (A2). |
| MA(7,2000) | RSAC/AQCR matching table. |
| NQ(3) | AQCR storage (3A1). |
| NR(4) | RSAC storage (4A1). |

F. <u>Program Listing to Match AQCR's to RSAC's (MATCH)</u>

```
C
C     PROGRAM MATCH  * MATCH AQCR TO RSAC OR STATE RSAC TO AQCR
C
C        IF MATCH IS NOT EXACT REJECT AQCR IS USED UNLESS
C         RSAC IS ONLY STATE (    1A00 MEANS AQCR 40 COVERS ALL
C                                 OF THE VIRGIN ISLANDS)
C
C     IF THE FIRST CHARACTER OF THE RSAC CODE POSITIONS (COL 2-5)
C        IS BLANK - IT IS ASSUMED THIS IS THE AQCR AND NOT THE RSAC
C
C      CONTROL CARDS - COL 1   COL 2   COL 3-5   COL 6   COL 7  COL 8-10
C
C         FIRST CARD -   9    (BLANK)    305       8       1(PR)  000
C       END OF GROUP -   8
C         END OF RUN -   9
C
C     SUBROUTINE RACONV PERFORMS MATCH FROM TAPE LIST OF RSAC VS AQCR
C
      DIMENSION DAT(4)
      DIMENSION NR(4),NQ(3),I305(3)
      DIMENSION NAME(6)
      COMMON IBL,I305,IZER1,IZER2
      READ 161,ININE,IBL,(I305(J),J=1,3),IEIGHT,IPRINT,IZER1,IZER2
  161 FORMAT(6A1,I1,A1,A2)
    5 CONTINUE
      PUNCH 102
  102 FORMAT(10H ++++++++          )
      INI = 0
      REWIND 1
    1 READ 103,ICTO,(NR(J),J=1,4),NS,(NQ(J),J=1,3),(DAT(J),J=1,4),
     1 (NAME(J),J=1,6)
  103 FORMAT(A1,4A1,A3,3A1,4F11.2,6A4)
      IF(ICTO-ININE) 2,1000,2
    2 CONTINUE
      IF(ICTO-IEIGHT) 6,5,6
    6 CONTINUE
      CALL RACONV(INT,NR,NQ)
      PUNCH 103,ICTO,(NR(J),J=1,4),NS,(NQ(J),J=1,3),(DAT(J),J=1,4),
     1 (NAME(J),J=1,6)
      IF(IPRINT) 31,31,30
   30 PRINT 104,ICTO,(NR(J),J=1,4),NS,(NQ(J),J=1,3),(DAT(J),J=1,4),
     1 (NAME(J),J=1,6)
  104 FORMAT(10X,A1,4A1,A3,3A1,4F11.2,6A4)
   31 CONTINUE
      GO TO 1
 1000 CONTINUE
      REWIND 1
      STOP
      END
      SUBROUTINE RACONV(INI,NR,NQ)
      DIMENSION MA(7,2000)
      DIMENSION JR(4),JP(3)
      DIMENSION NR(4),NQ(3),I305(3)
      COMMON IBL,I305,IZER1,IZER2
```

```
C
C     DIMENSION OF MA SHOULD BE CHANGED IF MATCH TABLE IS GREATER THAN
C                                                                 2000
C     START AND STOP OF REGIONS WOULD SPEED UP COMPARISONS
C
C     IREG SHOULD BE CHANGED IF THERE ARE MORE THAN 298 AQCR S
C
C
C
C     STMTS 10 THRU 70 READ IN MATCH TABLE
C
C     FIND RSAC FOR GIVEN AQCR (STMTS 90 THRU 190)
C
C     FIND AQCR FOR GIVEN RSAC (STMTS 200 ON)
C
      IREG = 298
      IF(INI)10,10,80
   10 INI = 1
      ICOUNT = 1
   20 READ(1,30,END=70,ERR=40)    (MA(J,ICOUNT),J=1,7)
   30 FORMAT(2X,3A1,4A1)
      ICOUNT = ICOUNT + 1
      GO TO 10
   40 PRINT 50,ICOUNT
   50 FORMAT(24H PARITY ERROR ON RECORD  ,I5,17H OF MATCH TABLE     )
      INI = INI + 1
      IF(INI-5) 20,20,60
   60 CONTINUE
      RETURN
   70 CONTINUE
      ICOUNT = ICOUNT + 1
C
   80 CONTINUE
      IF(NR(1)-IBLK) 200,90,200
   90 IF(NR(4)-IBLK) 120,100,120
  100 IF(NQ(3)-IBLK) 130,110,130
  110 NQ(1)=I305(1)
      NQ(2)=I305(2)
      NQ(3)=I305(3)
      RETURN
  120 CONTINUE
      NQ(1) = NR(2)
      NQ(2) = NR(3)
      NQ(3) = NR(4)
  130 DO 180 J=1,IREG
      IF(NQ(1)-MA(1,J)) 180,140,180
  140 IF(NQ(2)-MA(2,J)) 180,150,180
  150 IF(NQ(3)-MA(3,J)) 180,160,180
  160 DO 170 I=1,4
  170 NR(I) = MA(I+3,J)
      GO TO 190
  180 CONTINUE
  190 CONTINUE
      RETURN
C
  200 CONTINUE
      DO 260 J=IREG,ICOUNT
      IF(NR(1)-MA(4,J)) 260,210,260
  210 IF(NR(2)-MA(5,J)) 260,220,260
  220 IF(IZER1-MA(6,J)) 230,280,230
  230 IF(NR(3)-MA(3,J)) 260,240,260
  240 IF(IZER1-MA(7,J)) 250,280,250
  250 IF(NR(4)-MA(7,J)) 260,280,260
  260 CONTINUE
      DO 270 I=1,3
  270 NQ(I) = I305(I)
      RETURN
  280 DO 290 I=1,3
  290 NQ(I) = MA(I,J)
      RETURN
      END
```

```
***  INPUT DATA  ***


9 30581000                    COMMENTS AFTER COL TEN        PRINT OF ALL CARDS
 1111   71          140.04        91.18      546.16     179.23CARPENTER STEEL BRIDGEPO
 1111   75                                    43.57      26.64CARPENTER STEEL BRIDGEPO
 1561   71          287.02       186.86     1006.49     308.87C F AND I STEEL CORP ROE
 1561   75                                    80.29      47.65C F AND I STEEL CORP ROE
 1611   71          343.99       223.96     1076.71     422.48ALLEGHENY LUDLUM STEEL D
 1611   75                                    85.89      57.21ALLEGHENY LUDLUM STEEL D
 1631   71        25823.50     14124.03    18500.19    1237.45BETHLEHEM STEEL CORP LAC
 1631   71         8494.81      3485.38     6685.78     510.61REPUBLIC STEEL CORP BUFF
 1631   71         1481.67      1222.86     8766.31     312.07ERIE COUNTY, NY
 1631   75                                  1021.56      15.31BETHLEHEM STEEL CORP LAC
 16R4   71           50.49        32.87      156.04      66.09WICKWIRE BROTHERS CORTLA
 16R4   75                                    12.45       8.62WICKWIRE BROTHERS CORTLA
9


***  OUTPUT DATA  ***


 1111   71 37       140.04        91.18      546.16     179.23CARPENTER STEEL BRIDGEPO
 1111   75 37                                 43.57      26.64CARPENTER STEEL BRIDGEPO
 1561   71 10       287.02       186.86     1006.49     308.87C F AND I STEEL CORP ROE
 1561   75 10                                 80.29      47.65C F AND I STEEL CORP ROE
 1611   71188       343.99       223.96     1076.71     422.48ALLEGHENY LUDLUM STEEL D
 1611   75188                                 85.89      57.21ALLEGHENY LUDLUM STEEL D
 1631   71 18     25823.50     14124.03    18500.19    1237.45BETHLEHEM STEEL CORP LAC
 1631   71 18      8494.81      3485.38     6685.78     510.61REPUBLIC STEEL CORP BUFF
 1631   71 18      1481.67      1222.86     8766.31     312.07ERIE COUNTY, NY
 1631   75 18                               1021.56      15.31BETHLEHEM STEEL CORP LAC
 16R4   71305        50.49        32.87      156.04      66.09WICKWIRE BROTHERS CORTLA
 16R4   75305                                 12.45       8.62WICKWIRE BROTHERS CORTLA
```

# III. FILE MAINTENANCE PROGRAM

## A. Introduction

All cards that come from OUTFI or MATCH contain plant by plant pollution data and eventually all pollution data will need to be summed and displayed. Since some sources can have as many as 30,000 "plants," this large volume of data first needs to be stored on a master file that can be used by the report generators. Secondly, this file must, by necessity, be able to be updated or modified at any time. Program FILE provides a method of storing data as well as providing replacement, deletion, and insertion operations on an existing file when creating an updated file. A general flow chart for this program is shown in Figure W-3.

## B. Program Operation

As shown in Figure W-3, the basic operation is to create or update a data file. The decision to either create or update a file, and whether a list of the new file when updating is desired, is made at the beginning with the first control card. All other control cards relate to the updating process and allow cards to be deleted from the file, replaced, or have cards inserted into the file. It is obvious that the "new" or updated file could also be an extraction from the main data file for some special purpose since the old file is not automatically destroyed.

The only restriction in inserting, deleting, and replacing cards is that the operation must be in an ascending sequence.

## C. Input Data and Control Cards

The only restriction on input data is that there will be no punch in column 1 of the card since this column is used to define the insert, delete, and replace operations. The data supplied from OUTFI or MATCH do not contain any information in column one.

Table W-3 shows the layout of the control cards which are as follows:

1. Master control card - this card determines whether a file create or file update is to be done and if it is a file update,

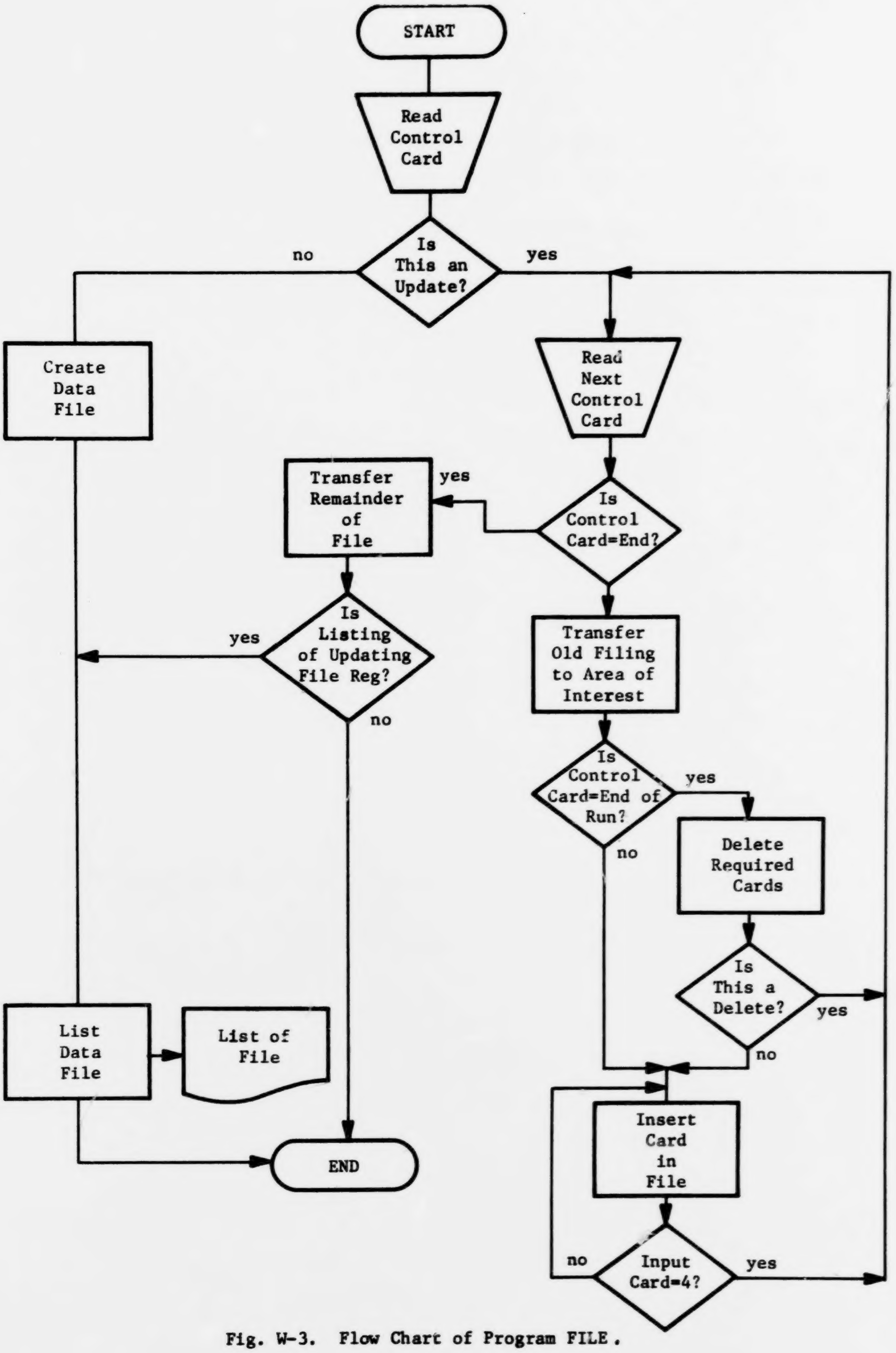

START
Read Control Card
Is This an Update?
no
yes
Create Data File
Read Next Control Card
Transfer Remainder of File
yes
Is Control Card=End?
Is Listing of Updating File Reg?
yes
no
Transfer Old Filing to Area of Interest
Is Control Card=End of Run?
yes
no
Delete Required Cards
Is This a Delete?
yes
no
List Data File
List of File
Insert Card in File
END
no
Input Card=4?
yes

Fig. W-3. Flow Chart of Program FILE.

## TABLE W-3. - CONTROL CARD LAYOUT

| Type of Card | Column 1 | Column 2 | Columns 11 - 15 | Columns 16 - 20 |
|---|---|---|---|---|
| Master Control | 0=file create<br>1=file update | 0=do not list new file<br>1=list new file | | |
| End of File | 5 | — | — | — |
| Replace Control (XXXXX thru YYYYY) | 1 | — | XXXXX | YYYYY |
| Delete Control (XXXXX thru YYYYY) | 2 | — | XXXXX | YYYYY |
| Insert Control (after XXXXX) | 3 | — | XXXXX | — |
| End of Insert or Replace Control | 4 | — | — | — |

whether a listing of the new file is needed. A listing is always given when a file is created from cards.

2. End of file control card - this card is used to indicate the end of the data for a file create or the end of all modifications in an update. It simply consists of a card with a five punched in column one. This card is required to terminate update procedures.
3. Replace control card - this card has a one punched in column one and columns 11-15 and 16-20 indicate cards to be replaced. This card is followed by the data cards to be put into the file instead. The data cards are terminated by an "end mod" card (four in column one), described in Section 6. If the second number is blank, only the number in columns 11-15 will be replaced.
4. Delete control card - this card has a two punched in column one and is used to delete cards on the old file from the new file. Columns 11-15 and 16-20 indicate the cards to be deleted. If columns 16-20 are blank, only the card identified by columns 11-15 will be deleted. This card need not be followed by an "end mod" card.
5. Insert control card - this card has a three in column one and columns 11-15 indicate where data cards are to be inserted. Data cards follow this card and are terminated by an "end mod" card.
6. End of modification control card ("end mod") - this card is simply a card with a four in column one. It is used to signal the end of data for an insert or replace statement and must follow these cards (after the cards to be inserted).

## D. Glossary of FORTRAN Names for File Maintenance Program (FILE)

| FORTRAN Name | Definition |
|---|---|
| | **Program FILE** |
| ICO | Input file counter. |
| ICON | Control card variable (see Table W-3). |
| ICTR | Type of run (=0, new file; =1, update). |
| ICTRO | File sequence number. |
| IIN | Insert print skip control. |
| IN(20) | Temporary data storage (19A4,A3). |
| IPRINT | ≠0, print new file. |
| IRRR | Input or output error indicator (=1 for error). |
| ISEQ | End of replace card not required when ISEQ=1. |
| ISTA | Start of file modification (I5). |
| ISTO | Stop of file modification (I5). |
| JCO | Output file counter. |
| | **Subroutine INP** |
| ICO | Input file counter. |
| ICOP | Old file sequence number. |
| ICTR | Sequence number at end of read operation. |
| IN(20) | Temporary data storage. |
| IRRR | Error in read indicator (=1 for error). |
| ITY | Delete or transfer code (=0, delete; =1, transfer). |
| JCO | Output file counter. |

### Subroutine OUT

| | |
|---|---|
| ICO | Input file counter. |
| ICTR | "Inserted" print control. |
| IN(20) | Temporary data storage. |
| JCO | Output file counter. |

## E. Program Listing to Create and Update a Master Data File (FILE)

```
C
C     PROGRAM TO CREATE AND UPDATE MASTER FILE
C
C     A 0 IN COL ONE OF FIRST CONTROL CARD INDICATES CREATE MASTER
C                FILE ON TAPE UNIT 11    -STOP BY END CORR CARD (5)
C
C     A 1 IN COL ONE OF FIRST CONTROL CARD INDICATES UPDATE OF MASTER
C                FILE - INPUT TAPE UNIT 10
C                     - OUTPUT TAPE UNIT 11    -STOP BY END CORR CARD
C                                                                (5)
C     UPDATE CONTROL CARDS -
C
C         TYPE        COLUMN-    1      2-10     11-15    16-20    21 UP
C
C     REPLACE XXXXX THRU YYYYY  1     REPLACE  XXXXX    YYYYY    (UNUSED)
C     DELETE XXXXX THRU YYYYY   2     DELETE   XXXXX    YYYYY    (UNUSED)
C     INSERT AT XXXXX           3     INSERT   XXXXX             (UNUSED)
C     END OF REP OR INSERT CDS  4     END MOD                    (UNUSED)
C     END OF ALL CORRECTIONS    5     END CORR                   (UNUSED)
C
C     THE NUMBER OF CARDS FOLLOWING A REPLACE OR INSERT CARD AND AN END
C        MOD CARD IS UNLIMITED
C
      COMMON ICO,JCO,ICON,IN
      DIMENSION IN(20)
      INTEGER EOF
      ICO = 0
      JCO = 0
      READ 99,ICTR,IPRINT
   99 FORMAT(2I1)
      IF(ICTR) 10,10,40
   10 CONTINUE
      IPRINT = 1
C
C     FILE CREATE SECTION
C
   20 READ 101,ICON,(IN(N),N=1,20)
  101 FORMAT(I1,19A4,A3)
      IF(ICON-5) 30,1001,1001
   30 CALL OUT(0)
      GO TO 20
   40 CONTINUE
   50 READ 104,ICON,ISTA,ISTO
  104 FORMAT(I1,9X,2I5)
      IIN = 0
      IF(ICON-2) 60,90,130
   60 ISTA = ISTA - 1
      ISEQ = 0
      CALL INP(ISTA,1,IRRR)
      IF(IRRR) 70,70,999
   70 READ 101,ICON,(IN(N),N=1,20)
      IF(ICON) 80,80,100
   80 IF(IIN) 81,81,83
   81 PRINT 82
  82 FORMAT(/)
  83 IIN = 1
     CALL OUT(1)
     GO TO 70
  90 CONTINUE
     ISEQ = 1
     ISTA = ISTA - 1
     CALL INP(ISTA,1,IRRR)
     IF(IRRR) 100,100,999
 100 ISTA = ISTA + 1
     IF(ISTO-ISTA) 110,110,120
 110 CALL INP(ISTA,0,IRRR)
     IF(IRRR) 50,50,999
 120 CALL INP(ISTO,0,IRRR)
     IF(IRRR) 50,50,999
 130 CONTINUE
     IF(ICON-4) 140,998,900
 140 CONTINUE
     ISEQ = 0
     CALL INP(ISTA,1,IRRR)
     IF(IRRR) 150,150,999
 150 READ 101,ICON,(IN(N),N=1,20)
     IF(ICON) 160,160,50
 160 IF(IIN) 161,161,163
 161 PRINT 82
 163 IIN = 1
     CALL OUT(1)
     GO TO 140
 900 CALL INP(ISTA,2,IRRR)
     IF(IRRR) 1000,1000,999
 998 IF(ISEQ) 999,999,50
 999 PRINT 105,ICO,JCO
 105 FORMAT(32H SEQUENCE ERROR    INPUT FILE =  ,I5, 5X ,
   1 15H OUTPUT FILE =  ,I5)
     PRINT 106, ICON,ISTA,ISTO
 106 FORMAT(/,22H CONTROL CARD   TYPE= ,I3,8H  START= ,I5,7H  STOP=,I5)
     PRINT 107
 107 FORMAT(/,20X,18H REMAINING CARDS   ,/)
 910 IF(ICON-5) 920,1005,1005
 920 READ 101,ICON,(IN(N),N=1,20)
     PRINT 103,ICON,(IN(N),N=1,20)
 103 FORMAT( 5X,I5,19A4,A3)
     GO TO 910
1000 REWIND 10
1001 ENDFILE 11
     REWIND 11
     IF(IPRINT) 1005,1005,1008
1008 CONTINUE
     DO 1004 I=1,JCO
     READ(11,108,ERR=1003,END=1002) (IN(N),N=1,20),ICTRO
 108 FORMAT(20A4,I5)
     PRINT 109,(IN(N),N=1,20),ICTRO
 109 FORMAT(19X,20A4,I5)
     GO TO 1004
1002 PRINT 111,I
 111 FORMAT(19H PREMATURE EOF AT  , I5 )
     GO TO 1005
1003 PRINT 112,I
 112 FORMAT(24H PARITY ERROR AT RECORD  , I5)
```

```
      GO TO 1005
 1004 CONTINUE
 1005 CONTINUE
      STOP
      END
      SUBROUTINE INP(ICTR,ITY,IRRR)
C
C     SUBROUTINE TO READ FROM MASTER FILE
C
C         TYPE  0=DELETE  1=TRANSFER  2=TRANSFER REMAINDER OF FILE
C
      COMMON ICO,JCO,ICON,IN
      DIMENSION IN(20)
      IF(ITY) 1,1,2
    1 PRINT 100
  100 FORMAT(/)
    2 CONTINUE
    5 IF (ICO-ICTR) 10,40,50
   10 READ(10,101,ERR=80,END=70) (IN(N),N=1,20),ICOP
  101 FORMAT(20A4,I5)
      ICO = ICO + 1
      IF(ITY) 20,20,30
   20 CONTINUE
      PRINT 102,(IN(N),N=1,20),ICOP
  102 FORMAT(14H *** DELETED  , 5X, 20A4,I5)
      GO TO 5
   30 CALL OUT(0)
      GO TO 5
   40 IRRR = 0
      RETURN
   50 CONTINUE
      IF(ITY-1) 60,60,10
   60 IRRR = 1
      RETURN
   70 PRINT 103,ICO
  103 FORMAT(30H END OF FILE ON INPUT FILE AT   , I5, 8H RECORDS )
      GO TO 40
   80 PRINT 104,ICO
  104 FORMAT(30H INPUT PARITY ERROR ON RECORD  , I5 )
      GO TO 60
      END
      SUBROUTINE OUT(ICTR)
C
C     PROGRAM TO OUTPUT NEW MASTER FILE
C
C     ICTR   0=TRANSFER    1=INSERT
C
      COMMON ICO,JCO,ICON,IN
      DIMENSION IN(20)
      JCO = JCO + 1
      WRITE(11,101,ERR=30) (IN(N),N=1,20),JCO
  101 FORMAT(20A4,I5)
      IF(ICTR) 20,20,10
   10 PRINT 102,(IN(N),N=1,20),JCO
  102 FORMAT(14H *** INSERTED ,5X,20A4,I5)
   20 CONTINUE
      RETURN
   30 PRINT 103,JCO
  103 FORMAT(30H PARITY ERROR ON OUTPUT RECORD  ,I5)
```

```
      GO TO 20
      END

***  TYPICAL RUN CONTROL DECK  ***

***  INPUT DATA  ***


1
1              11   12
 1111  71 37     140.04       91.18      546.16       179.23CARPENTER STEEL BRIDGEPO
 1111  75 37                              43.57        26.64CARPENTER STEEL BRIDGEPO
4
3              14
 1561  71 10     287.02      186.86     1006.49       308.87C F AND I STEEL CORP ROE
 1561  75 10                              80.29        47.65C F AND I STEEL CORP ROE
 1611  71188     343.99      223.96     1076.71       422.48ALLEGHENY LUDLUM STEEL D
 1611  75188                              85.89        57.21ALLEGHENY LUDLUM STEEL D
 1631  71 18   25823.50    14124.03    18500.19      1237.45BETHLEHEM STEEL CORP LAC
 1631  71 18    8494.81     3485.38     6685.78       510.61REPUBLIC STEEL CORP BUFF
 1631  71 18    1481.67     1222.86     8766.31       312.07ERIE COUNTY, NY
 1631  75 18                            1021.56        19.31BETHLEHEM STEEL CORP LAC
 16R4  71305      50.49       32.87      156.04        66.09WICKWIRE BROTHERS CORTLA
 16R4  75305                              12.45         8.62WICKWIRE BROTHERS CORTLA
4
5 END MODS
```

## IV. REPORT GENERATOR PROGRAMS

### A. Introduction

The data from the master file must be summed into proper groupings, growth calculated, implementation applied, and results displayed. The report generator consists of two programs:

1. SEARCH - Program SEARCH searches the input data file for data for a specified grouping (AQCR, aggregate AQCR, etc.). Yearly growth factors are also applied to the pollutants and costs for future extrapolation.
2. PRINT - Program PRINT prints the source pollutant levels, predicted future levels, and cost of implementing control schemes over a designated time period for the grouped data supplied from Program SEARCH.

### B. Program Operation

Although Programs SEARCH and PRINT are at present two separate programs, no difficulty in chaining their operation would be encountered with a large computer. Figure W-4 shows the overall flow of the report generator programs. These programs will be discussed separately although Program SEARCH does not produce any printed output.

#### 1. Program SEARCH

Program SEARCH provides an all source, all pollutant output to Program PRINT. The output is a summary of a designated geographical area and includes yearly growth estimates. Figure W-5 shows an overall flow chart of Program SEARCH with Subroutine READ and Subroutine OUTBO not shown. Each major summation subroutine (RINPUT, SINPUT, AINPUT, and TINPUT) uses Subroutine READ to input plant by plant input and Subroutine OUTBO to write out the aggregate data.

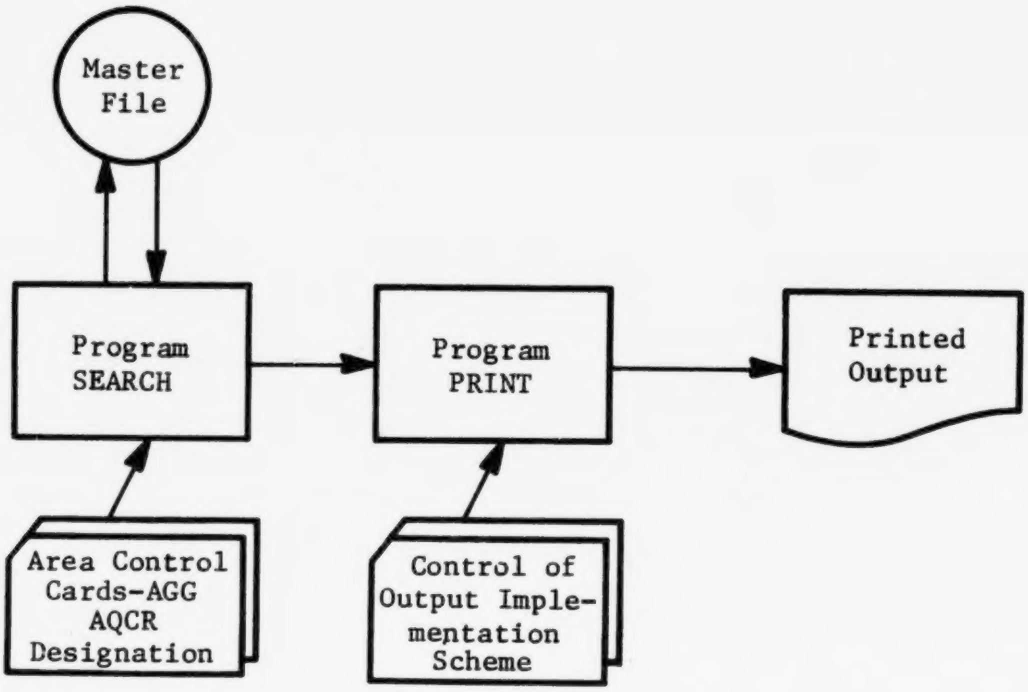

Master
File
Program
SEARCH
Program
PRINT
Printed
Output
Area Control
Cards-AGG
AQCR
Designation
Control of
Output Imple-
mentation
Scheme

Fig. W-4. Report Generator Flow Chart .

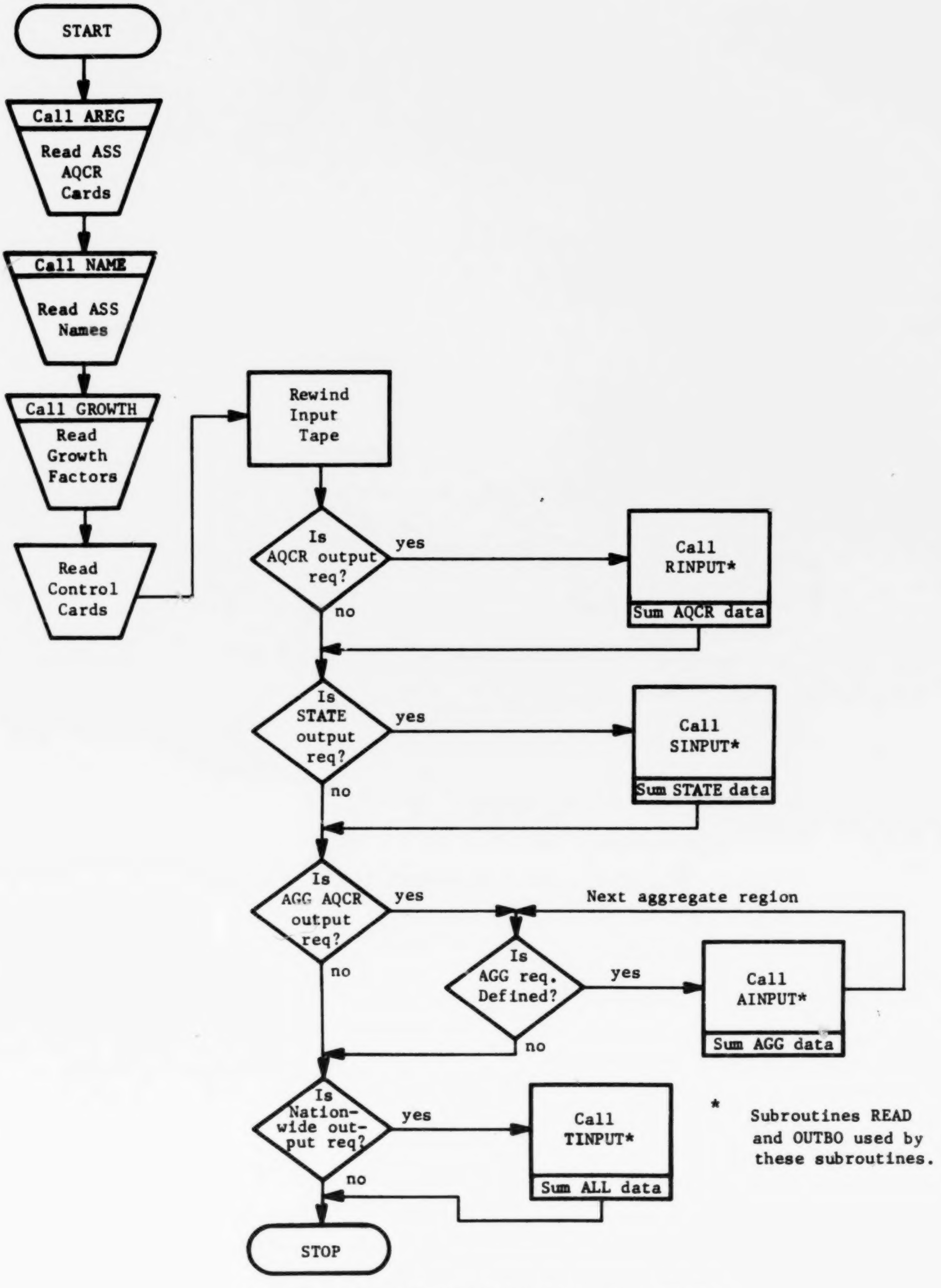

START
Call AREG
Read ASS AQCR Cards
Call NAME
Read ASS Names
Call GROWTH
Read Growth Factors
Read Control Cards
Rewind Input Tape
Is AQCR output req?
yes
no
Call RINPUT*
Sum AQCR data
Is STATE output req?
yes
no
Call SINPUT*
Sum STATE data
Is AGG AQCR output req?
yes
no
Next aggregate region
Is AGG req. Defined?
yes
no
Call AINPUT*
Sum AGG data
Is Nation-wide output req?
yes
no
Call TINPUT*
Sum ALL data
STOP
* Subroutines READ and OUTBO used by these subroutines.

Fig. W-5. General Flow Chart of Program SEARCH.

a) AREG - this subroutine reads the first 305 columns from four cards. Each of these columns contain the number 1-9, depending on which "Aggregate AQCR" a particular AQCR falls (i.e., a two in column 20 would put AQCR 20 data into "Aggregate Region" two).

b) NAME - this subroutine simply reads in the names of the 50 states, District of Columbia, Puerto Rico, the Virgin Islands, and aggregate AQCR's.

c) GROWTH - this subroutine reads in the fraction growth of each source. Both the fraction increase in capacity and production on a nationwide basis is used as input. These data are contained on six cards. Exact layout is given in Section III, Paragraph C.

d) RINPUT - this subroutine calls Subroutine READ until all input data for a specific AQCR are summed and then Subroutine OUTBO is called to estimate growth and write an output record. This is repeated for all AQCR's.

e) SINPUT - this subroutine calls Subroutine READ for all data pertaining to a particular state. Subroutine OUTBO is called when all data have been summed.

f) AINPUT - this subroutine calls Subroutine READ and sums data until all data for a designated "Aggregate AQCR" have been found. Subroutine OUTBO is then called to produce an output record.

g) TINPUT - this subroutine sums all data contained on the master data file. The summation and growth is written out by Subroutine OUTBO.

h) READ - Subroutine READ finds individual plant data and returns it to whatever subroutine calls for the data. Typically the data come from the master file although through an option on the control card, card input may be used; however, no recycle is possible and therefore only one output set is available for card input (i.e., only "Aggregate AQCR" output).

i) OUTBO - Subroutine OUTBO serves two functions: (1) estimate the yearly growth of cost and emissions for all sources and include this in the output, and (2) write the output that contains the 1967 and one year growth costs and emissions. The growth is simply a multiplication of the inputed source growth values (capacity and production) times the 1967 base costs and emissions. (The number of years of growth is applied in Program PRINT.) The output is a large binary output record that is used directly by PRINT.

## 2. Program PRINT

Program PRINT receives data from SEARCH, applies the designated number of years to the growth and costs, and prints out a summary of costs, emissions, and implementation schedule. Figure W-6 shows the general flow chart for Program PRINT. Along with the implementation card is the start date of the implementation and the termination date of the projected costs, emissions, and implementation.

a) NAME - Subroutine NAME reads in the names of each source (16 characters) and each pollutant (8 characters) that are used as labels in the printed output.

b) IMPL - this subroutine reads in the starting date of the implementation, the date of the final implementation and a "variable" implementation scheme. This "variable" implementation scheme allows a specific source (or all sources) to be less than fully implemented during the designated implementation period. A name of 40 characters describing this scheme is also available for identification. (Note: both full implementation and "variable" implementation schemes are printed.)

c) OUTBI - this subroutine reads in the data from SEARCH and returns an end of file indicator which is used to terminate the run.

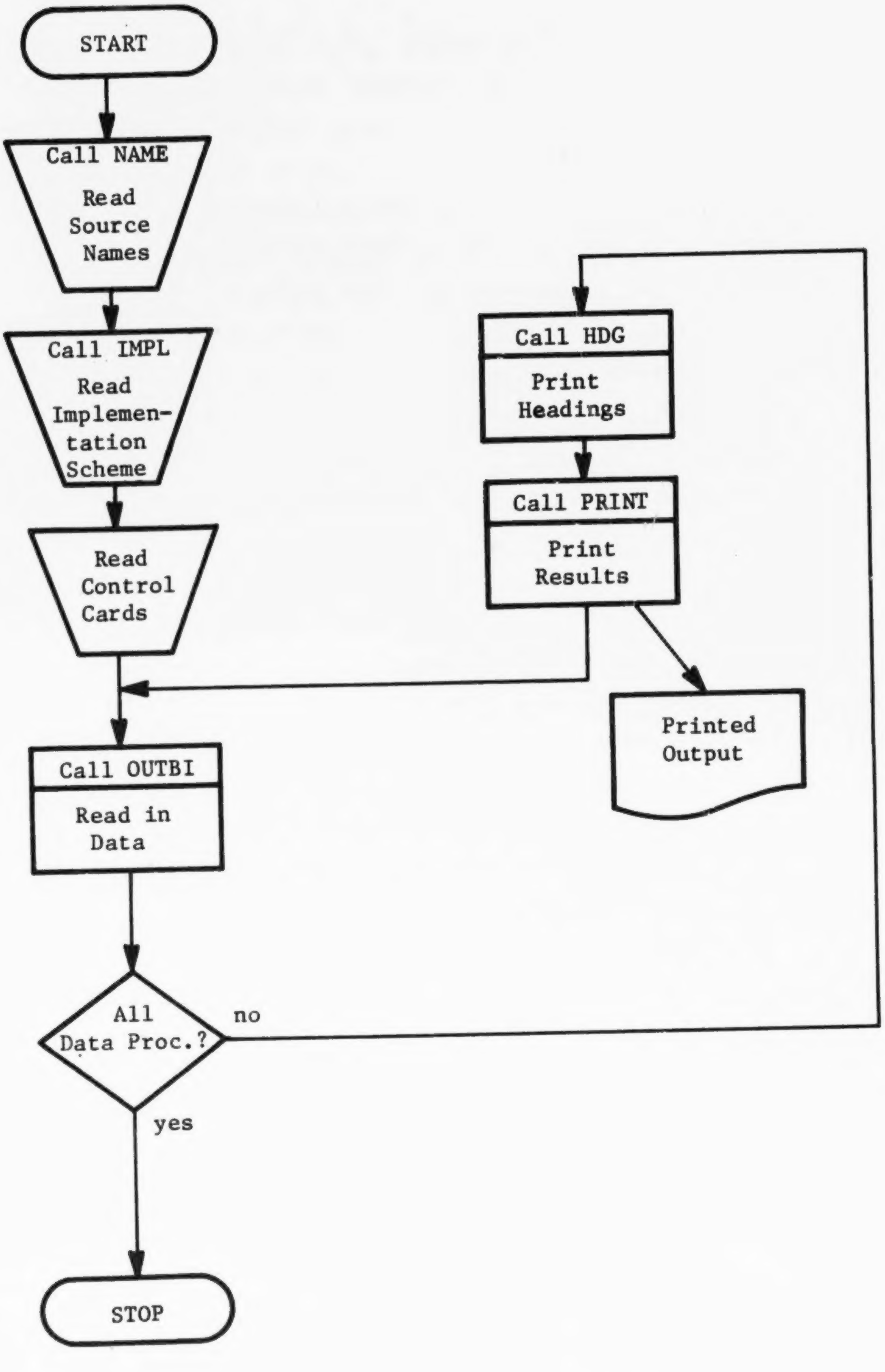

START
Call NAME
Read Source Names
Call IMPL
Read Implementation Scheme
Read Control Cards
Call OUTBI
Read in Data
All Data Proc.?
no
yes
STOP
Call HDG
Print Headings
Call PRINT
Print Results
Printed Output

Fig. W-6. General Flow Chart for Program PRINT.

d) HDG - this subroutine simply prints the correct heading for the printed output depending on whether the data from OUTBI was for an AQCR, State, Aggregate AQCR, or National Summary. (This subroutine is also called by the implementation part of Subroutine PRINT.)

e) PRINT - Subroutine PRINT is designed to control the printing of the source costs and emissions, emissions, and implementation. A general flow chart for Subroutine PRINT is shown in Figure W-7. Beginning with Calendar Year 1967, the growth is computed by multiplying the yearly growth times the differences between the final years of implementation. The three printing subroutines called by PRINT are:

   1) SOURCE - this subroutine prints each source by total pollution and if there is more than one pollutant each pollutant contributes to this contamination. The printout is separated by source and, therefore, all specific pollutants are not summed.

   2) POLUT - Subroutine POLUT prints the sum of the specific pollutants that comprise the geographical area being printed.

   3) IMPLI - Subroutine IMPLI prints the full and "variable" implementation schemes, separated by source, for the geographical area being printed. Typically an implementation scheme is not printed for a geographical area smaller than an Aggregate AQCR.

## C. Input Data

Input to the report generator programs typically comes in two forms as was shown in Figure W-4: (1) tape file data, and (2) control cards. Program SEARCH also has a card input option to bypass FILE if necessary for a "quick" printout.

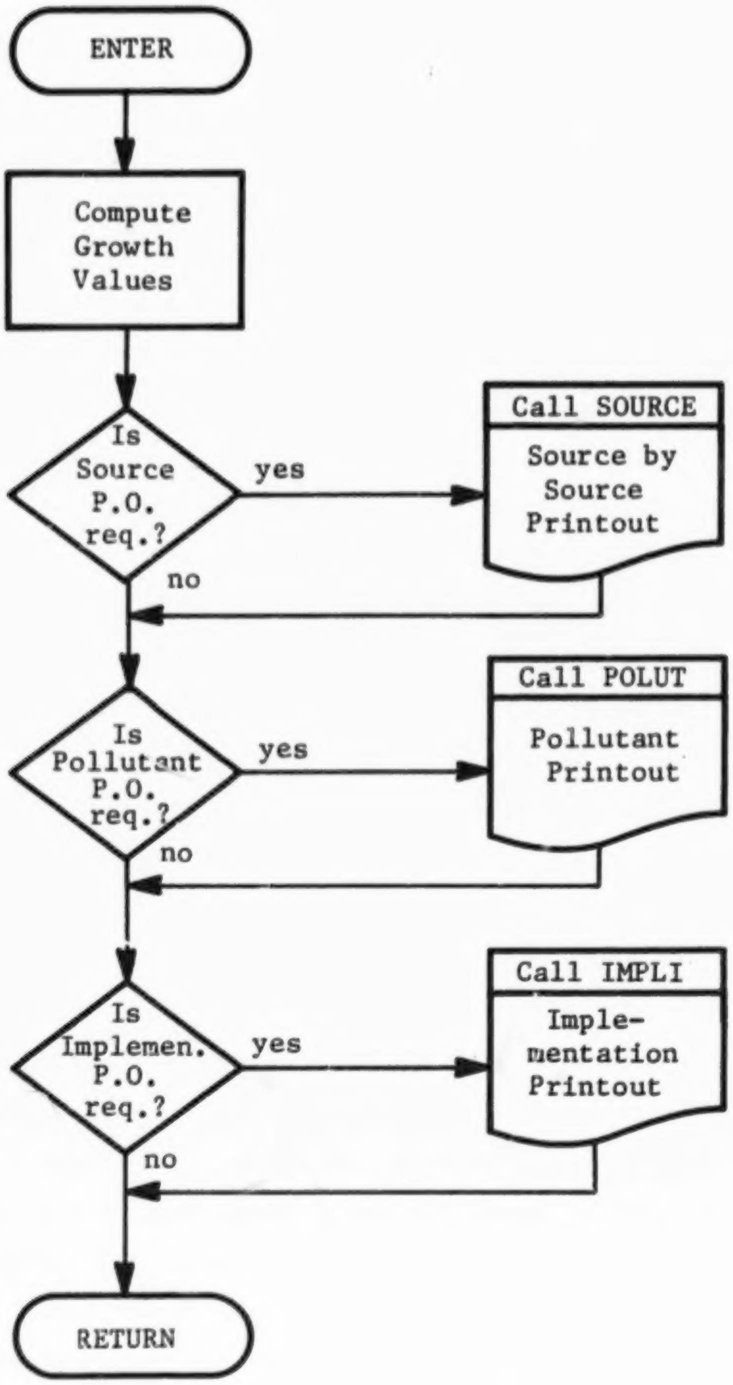

ENTER
Compute Growth Values
Is Source P.O. req.?
yes
no
Call SOURCE
Source by Source Printout
Is Pollutant P.O. req.?
yes
no
Call POLUT
Pollutant Printout
Is Implemen. P.O. req.?
yes
no
Call IMPLI
Implementation Printout
RETURN

Fig. W-7.- General Flow Chart for Subroutine PRINT of Program PRINT.

1. Program SEARCH

The input data comes from either OUTFI, MATCH, or FILE and was shown in Table W-2. The control cards for Program MATCH are:

a) Aggregate AQCR designation - the first 305 columns of these cards (3 full cards, 1 partial card) designate into which Aggregate AQCR (1-9) a particular AQCR (1-305) should fall (i.e., a two in column 10 indicates AQCR 10 (See Section V) should be in aggregate region two). The only restriction is that all AQCR numbers should have an Aggregate AQCR number or these data will be lost in an Aggregate AQCR printout.

b) Names of states and Aggregate AQCR's - the names of the 50 states, District of Columbia, Puerto Rico, and the Virgin Islands, and the ten possible AQCR's are entered by a series of cards. One card is used for each state name and is read into the program with the RSAC state code in columns 9 and 10 and the name in columns 21 through 40. Similarly the ten Aggregate AQCR names are entered from columns 21 through 40 of the next ten cards.

c) Growth factors - the yearly growth estimates for capacity and production increase for each source is entered in order of the source code given in Section V. The card layout is shown in Table W-4. Each entry is in a fractional increase during a year. A total of six cards is required.

d) Control Cards - certain options are available and Table W-5 shows the control card layout for Program SEARCH. Card input option should be used only in obtaining a "quick" output with card separator "8" cards used to separate decks instead of sorting data by AQCR. Only the Aggregate printout should be used with card input!

Under normal data file operation, it is possible to obtain AQCR, State, Aggregate AQCR, and Nationwide results from one run by setting all output keys (Columns 11-14) or any combination of these outputs.

## 2. Program PRINT

The input comes from both SEARCH and in the form of input cards. The exact form of the input data from SEARCH is unimportant since it is simply a temporary storage of internal memory which is read back into memory as required by PRINT.

The input cards for PRINT are:

a) Source and Pollutant names - these names are read in from cards with the first ten columns blank and the source name (in order given in Section V) in columns 11-26. A card with a two in column ten is used to signal that all source names have been read into memory. After the source names have been read, the pollutant names are read in from cards. The names of the pollutants are in columns 11-18 with a card following the name cards containing a two in column ten to signal the end to the pollutant names.

b) Implementation Schemes - Table W-6 shows the implementation of the implementation cards. The growth displayed in the model will be the year given as the end of the implementation period, and implementation will be given from the implementation start through the end of implementation. All nonspecific source implementation fractions use the initial fraction given on card two.

c) Control card (options) - Table W-7 shows the setup of the PRINT control card. Typically the run will use a blank control card although some runs will require the options shown.

TABLE W-4. - CARD LAYOUT FOR THE GROWTH INPUT DATA

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | **Card 1** | | |
| | Blank. | 1-5 | 5X |
| GRN(I)<br>I=1,14 | First 14 capacity growth factors. | 6-75 | 14F5.3 |
| | **Card 2** | | |
| | Blank. | 1-5 | 5X |
| GRN(I)<br>I=15,28 | Second 14 capacity growth factors. | 6-75 | 14F5.3 |
| | **Card 3** | | |
| | Blank. | 1-5 | 5X |
| GRN(I)<br>I=29,34 | Remaining capacity growth factors. | 6-35 | 6F5.3 |
| | **Card 4** | | |
| | Blank. | 1-5 | 5X |
| GRNP(I)<br>I=1,14 | First 14 production growth factors. | 6-75 | 14F5.3 |
| | **Card 5** | | |
| | Blank. | 1-5 | 5X |
| GRNP(I)<br>I=15,28 | Second 14 production growth factors. | 6-75 | 14F5.3 |
| | **Card 6** | | |
| | Blank. | 1-5 | 5X |
| GRNP(I)<br>I=29,34 | Remaining production growth factors. | 6-35 | 6F5.3 |

TABLE W-5. - CONTROL CARD LAYOUT FOR PROGRAM SEARCH

| Column | Operation |
|---|---|
| 1-10 | blank |
| 11 | =1 for individual region printout |
| 12 | =1 for state printout |
| 13 | =1 for Aggregate printout |
| 14 | =1 for national summary printout |
| 15-18 | not used. |
| 19 | =1 for card input option |
| 20 | =1 for card input separated by "8" cards for partial data reports. |

TABLE W-6. - IMPLEMENTATION INPUT CARD LAYOUT

| FORTRAN Name | Definition | Card Columns | FORTRAN Format |
|---|---|---|---|
| | Card 1 | | |
| IMPN(I) I=1,10 | Name of implementation scheme. | 1-40 | 10A4 |
| | Card 2 | | |
| ICTR | Card control (=1 if individual source card is to follow). | 1 | I1 |
| TSTART | Start date of implementation. | 2-10 | F9.0 |
| TSTOP | Stop date of implementation. | 11-20 | F10.0 |
| PER | Fraction of full implementation available in implementation scheme. | 21-30 | F10.0 |
| | Card 3 | | |
| ICTR | Card control (=0 if last card, =1 if more are to follow). | 1 | I1 |
| ISOU | Specific source code. | 2-3 | I2 |
| | Blank . | 4-20 | 17X |
| PER | Fraction of full implementation available in implementation scheme for this specific source. | 21-30 | F10.0 |

TABLE W-7. - PROGRAM PRINT CONTROL CARD OPTIONS

| Columns | Option |
|---|---|
| 1-10 | blank |
| 11-15 | not used |
| 16 | =1, provide implementation at AQCR level. |
| 17 | =1, drop cost summary line in printout. |
| 18 | =1, drop implementation printout. |
| 19 | =1, drop pollutant printout. |
| 20 | =1, drop source printout. |

## D. Glossary of FORTRAN Names for Report Generator Programs

### Program SEARCH

| FORTRAN Name | Definition |
|---|---|
| GRN(34) | Capacity growth factors (F5.3). |
| GRNP(34) | Production growth factors (F5.3). |
| IBLK | Alphanumeric blank (A4). |
| ICTR | End of input file indicator (≠0). |
| IOPT(10) | Control card data (see Table W-5). |
| IPOL | Pollutant code. |
| IPOLU(9,2) | Pollutant names (2A4). |
| ISO | Source code. |
| ISOUR(34,4) | Source names (4A4). |
| JEOF | End of file indicator. |
| JREG(305) | Aggregate region matrix (305I1). |
| JREGP | Temporary region storage. |
| JST | Start indicator (=0, rewind file). |
| KREG | Area being summed. |
| KTYPE | Type of output (=1, AQCR; =2, Aggregate AQCR; =3, national output; =4, state output. |
| MREG | AQCR found on file. |
| MRSAC | First two digits of RSAC code. |
| NAMER(10,6) | Aggregate AQCR code and names (A2, 5A4). |
| NAMES(53,6) | State codes and names (A2, 5A4). |
| NARE(5) | Name of output area. |
| PODATA(34,9,8) | Output data matrix. |
| POP | Population. |
| PTDATA(8) | Input data (temporary). |

### Subroutine AREG

| FORTRAN Name | Definition |
|---|---|
| JREG(305) | Aggregate AQCR identification (305I1). |

### Subroutine NAME

| FORTRAN Name | Definition |
|---|---|
| NAMER(10,6) | Aggregate AQCR code and name (8X,A2, 10X, 5A4). |
| NAMES(53,6) | State code and name (8X,A2,10X,5A4). |

## Subroutine GROWTH

| | |
|---|---|
| GRN(34) | Capacity growth factors (F5.3). |
| GRP(34) | Production growth factors (F5.3). |

## Subroutine RINPUT

| | |
|---|---|
| ICK | Start of region input KEY. |
| IPOL | Pollutant code. |
| ISO | Source code. |
| KREG | Area being summed. |
| MREG | Area found on file. |
| PODATA(34,9,8) | Output data. |
| PTDATA(10) | Input data (part). |

## Subroutine AINPUT

| | |
|---|---|
| ICTR | End of file indicator (≠0). |
| IPOL | Pollutant code. |
| ISO | Source code. |
| ITREG | Aggregate AQCR for area MREG. |
| JREG(305) | Aggregate AQCR matrix. |
| JST | Next data record read-indicator. |
| MREG | Input data area. |
| MRSAC | First two digits of RSAC. |
| PODATA(34,9,8) | Output data. |
| PTDATA(8) | Input data. |

## Subroutine SINPUT

| | |
|---|---|
| ICTR | End of file indicator (≠0). |
| ILOC | Alphanumeric state code (first two digits of RSAC). |
| IPOL | Pollutant code. |
| ISO | Source code. |
| JST | Next data record read-indicator. |
| MRSAC | Area found on file. |
| PODATA(34,9,8) | Output data. |
| PTDATA(8) | Input data. |

## Subroutine TINPUT

| | |
|---|---|
| ICTR | End of file indicator (≠0). |
| IPOC | Pollutant code. |
| ISO | Source code. |
| PODATA(34,9,8) | Output data. |
| PTDATA(8) | Input data |

## Subroutine READ

| | |
|---|---|
| ICTR | End of file indicator (≠0). |
| ICTRT(5) | Temporary storage of ICTR for next five records. |
| IOPT(10) | Control card data (see Table W-5). |
| IPOL | Pollutant code. |
| IPOLT(5) | Temporary storage of IPOL for next five records. |
| ISO | Source code. |
| ISOT(5) | Temporary storage of ISO for next five records. |
| JCTR | Record index. |
| JEOF | End of file indicator for read operation. |
| JST | Start indicator. |
| MREG | AQCR. |
| MREGT(5) | Temporary storage of MREG for next five records. |
| MRSA(5) | Temporary storage of MRSAC for next five records. |
| MRSAC | First two digits of the RSAC code. |
| PTDATA(8) | Pollution and cost data. |
| PTEM(5,8) | Temporary storage of PTDATA for next five records. |

## Subroutine OUTBO

| | |
|---|---|
| GROWP(34) | Capacity growth factors (GRN). |
| GROWTH(34) | Production growth factors (GRNP). |
| KREG | Area being summed. |
| KTYPE | Type of output (see Program SEARCH list. |
| PODATA | Output data. |

## Program PRINT

| | |
|---|---|
| IEO | Input parity error or end of file (≠0). |
| IMPN(10) | Implementation name (10A4). |
| IOPT(10) | Control card codes (10I1). |
| IPOLU(9,2) | Pollutant names (2A4). |
| ISOUR(34,4) | Source names (4A4). |
| JIDENT | Dummy variable. |
| KREG | Area being printed. |
| KTYPE | Type of summary (see Program SEARCH). |
| NARE(5) | Name of area being printed (5A4). |
| NSOU | Number of source names. |
| OUT(8) | Temporary output variable. |
| PODATA(34,9,8) | Input data. |
| POPULA | Population. |
| TOUT(8) | Temporary output totals variable. |
| TPER(34) | Fraction implementation by source. |
| TSTART | Date to start implementation. |
| TSTOP | Date to complete implementation. |

## Subroutine NAME

| | |
|---|---|
| ICTR | Control character (=2 indicates end). |
| IPOLU(9,2) | Pollutant names. |
| ISOUR(34,4) | Source names. |
| NSOU | Number of source names. |

## Subroutine IMPL

| | |
|---|---|
| ICTR | Control character (=1 for stop). |
| IMPN(10) | Implementation name (10A4). |
| ISOU | Source code. |
| PER | Implementation fraction. |
| TPER(34) | Implementation fraction (by source). |
| TSTART | Start date of implementation. |
| TSTOP | Stop date of implementation. |

## Subroutine PRINT

| | |
|---|---|
| IOPT(10) | Control card variable. |
| ISTOP | Implementation stop date. |
| PODATA(34,9,8) | Input data. |
| TDIF | Difference between TSTART and end of Calendar Year 1968. |
| TSTART | Date to start implementation. |
| TSTOP | Date to stop implementation. |

## Subroutine SOURCE

| | |
|---|---|
| IPOLU(9,2) | Pollutant names (2A4). |
| ISOUR(34,4) | Source names (4A4). |
| OUT(8) | Temporary output variable. |
| PODATA | Input data. |
| TOUT(8) | Temporary output total variable. |

## Subroutine POLUT

| | |
|---|---|
| IPOLU(9,2) | Pollutant names (2A4). |
| OUT(8) | Temporary output variable. |
| PODATA(34,9,8) | Input data. |
| TOUT(8) | Temporary output totals variable. |

## Subroutine IMPLI

| | |
|---|---|
| IDATE | Date index in printing. |
| IMPN(10) | Implementation name (10A4). |
| ISOUR(34,4) | Source name (4A4). |
| ISTART | Start date of implementation. |
| ISTOP | Stop date of implementation. |
| OUT(8) | Temporary output variable. |
| PERAL | Fraction of implementation (total) per year. |
| PODATA(34,9,8) | Input data. |
| POO(2) | Temporary pollutant output variable. |
| POP(2) | Temporary pollutant output variable. |
| TDATE | Date index in printing. |
| TPERP | Fraction of specific implementation per year. |
| TOUT(8) | Temporary output total variable. |
| TSTART | Start date of implementation |
| TSTOP | Stop date of implementation. |

## Subroutine HDG

| | |
|---|---|
| KREG | Area. |
| KTYPE | Output summary area code. |
| NARE(5) | Area name (5A4). |

## Subroutine OUTBI

| | |
|---|---|
| IEO | Parity error, end of file, or read indicator. |

## E. Program Listing for Report Generator Programs

### 1. Program Listing for Program SEARCH

```
C
C     A P C O SEARCH PROGRAM
C
C
C     THIS PROGRAM SEARCHES DATA FILE TO PROVIDE -
C
C              REGION (AQCR) OUTPUT        IOPT(1) = 1   SUB RINPUT
C              STATE OUTPUT                IOPT(2) = 1   SUB SINPUT
C              AGGREGATE REGION OUTPUT     IOPT(3) = 1   SUB AINPUT
C              NATIONWIDE OUTPUT           IOPT(4) = 1   SUB TINPUT
C
C     SUBROUTINES -
C         AREG - DETERMINE COMPOSITION OF AGGREGATE NAPCA REGIONS (1-9)
C         NAME - READ IN NAMES OF STATES AND AGGREGATE REGIONS
C         GROWTH - READ IN GROWTH VALUES FOR ALL SOURCES - ALL REGIONS
C         READ - INPUT DATA PROCESSING SUBROUTINE
C         ERRR - PRINT OF TRACE
C         RINPUT,SINPUT,AINPUT,TINPUT - SUBROUTINES PERFORMING REQUIRED
C                                       SUMMATIONS OF INPUT DATA
C         OUTBO - SUBROUTINE TO WRITE OUTPUT ON TAPE FOR LATER USE
C
C     ASSUMES DATA ON TAPE OR SOME REVERSABLE MEDIUM
C
C     IOPT(1) INDICATES REGION PRINTOUT DESIRED
C     IOPT(2) INDICATES AGGREGATE PRINTOUT DESIRED
C     IOPT(3) INDICATES GRAND TOTAL PRINTOUT DESIRED
C
C     IOPT(10) INDICATES CARD INPUT (ONLY) OPTION - MASTER FILE NOT USED
C
C     IOPT(9)  INDICATES CARD INPUT IS IN SPECIFIC NON-ORDERED PACKETS
C                        AND EACH PACKET IS SEPARATED BY A CARD WITH
C                                            AN 8 IN COLUMN ONE
C
C       ASSUMPTION - IF IOPT(9) IS ZERO AND IOPT(10) IS POS - CARD DATA
C                      INPUT IS SORTED INTO ASSENDING ORDER BY AQCR NO.
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG,IOPT
      DIMENSION IOPT(10),PODATA(34,9,8),ISOUR(34,4),IPOLU(9,2)
      DIMENSION OUT(8),TOUT(8),PTDATA(8)
      DIMENSION TPER(34),IMPN(10),JREG(305)
      DIMENSION NARE(5)
      DIMENSION NAMES (53,6),NAMER(10,6)
      DIMENSION GRN(34),GRNP(34)
      CALL AREG
      CALL NAME(NAMES,NAMER)
      CALL GROWTH(GRN,GRNP)
      READ 101,(IOPT(N),N=1,10),IBLK
  101 FORMAT(10X,10I1,A4)
      JST = 0
      CALL READ(ICTR,MRSAC,MREG,ISO,IPOL,PTDATA,JEOF,JST)
      IF (JEOF) 8,8,999
    8 CONTINUE
      PRINT 125,(IOPT(JJ),JJ=1,10)
  125 FORMAT(10H  ** CODES       ,10I5)
```

```
      IF(IOPT(1)) 2,2,1
    1 CALL RINPUT(ICTR)
      DO 30 N=1,5
   30 NARE(N) =  IBLK
      CALL OUTBO(GRN,GRNP)
      IF(ICTR-9) 1,1,2
    2 IF(IOPT(2)) 49,49,40
   40 JST = 1
      DO 41 KREG=1,53
      CALL SINPUT(NAMES(KREG,1),ICTR,JST)
      DO 32 N=1,5
   32 NARE(N) =  NAMES(KREG,N+1)
      CALL OUTBO(GRN,GRNP)
   41 CONTINUE
   49 JST = 1
      IF(IOPT(3)) 5,5,3
    3 DO 4 KREG=1,9
      DO 60 N=1,305
      JREGP = JREG(N)
      IF(KREG-JREG(N)) 60,61,60
   60 CONTINUE
      GO TO 4
   61 CONTINUE
      CALL AINPUT(ICTR,JST)
      DO 31 N=1,5
   31 NARE(N) =  NAMER(KREG,N+1)
      CALL OUTBO(GRN,GRNP)
      IF(IOPT(9)) 201,201,200
  200 IF(ICTR-9) 49,202,202
  201 CONTINUE
      IF(ICTR-8) 660,49,202
  660 CONTINUE
    4 CONTINUE
  202 CONTINUE
    5 IF(IOPT(4)) 7,7,6
    6 CONTINUE
      CALL TINPUT
      DO 33 N=1,5
   33 NARE(N) = IBLK
      CALL OUTBO(GRN,GRNP)
    7 CONTINUE
      ENDFILE 11
      REWIND 11
      GO TO 1000
  999 PRINT 901
  901 FORMAT(31H NO INPUT DATA - RUN CANCIELED  )
 1000 CONTINUE
      END
      SUBROUTINE AREG
C
C     THIS SUBROUTINE READS THE NAPCA REGIONS COMPRIZING EACH
C               AGGREGATE NAPCA CONTROL AREA (1-9)
C
C     A NON DEFINED REGION IS SET TO 10 AND ASSUMED NON DEFINED
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG
      DIMENSION PODATA(34,9,8),NARE(5),JREG(305)
      READ 101,(JREG(N),N=1,305)
  101 FORMAT(80I1,/,80I1,/,80I1,/,65I1)
```

```
      DO 2 N=1,305
      IF(JREG(N)) 1,1,2
    1 JREG(N)=10
    2 CONTINUE
      RETURN
      END
      SUBROUTINE NAME(NAMES,NAMER)
C
C     THIS SUBROUTINE READS IN NAMES OF AGGREGATE REGIONS AND STATES
C
      DIMENSION NAMES (53,6),NAMER(10,6)
      KTYPE = 4
      DO 1 N=1,53
    1 READ 101,(NAMES(N,J),J=1,6)
  101 FORMAT(8X,A2,10X,5A4)
      DO 2 N=1,10
    2 READ 101,(NAMER(N,J),J=1,6)
      RETURN
      END
      SUBROUTINE GROWTH(GRN,GRP)
C
C     NATIONAL GROWTH FACTORS
C
      DIMENSION GRN(34),GRP(34)
      READ 101,(GRN(N),N=1,28),IEND,ISPEC,(GRN(N),N=29,34)
  101 FORMAT(5X,14F5.3,/,5X,14F5.3,/,I1,I2,2X, 6F5.3)
      READ 101,(GRP(N),N=1,28),IEND,ISPEC,(GRP(N),N=29,34)
      RETURN
      END
      SUBROUTINE RINPUT(ICTR)
C
C     THIS SUBROUTINE ACCUMULATES DATA FOR A REGION FOR OUTPUT
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG
      DIMENSION PODATA(34,9,8),NARE(5),JREG(305),PTDATA(8)
      KTYPE = 1
      DO 10 I=1,34
      DO 10 J=1,9
      DO 10 K=1,8
   10 PODATA(I,J,K) = 0.0
      ICK = 0
    1 JST = 1
      CALL READ(ICTR,MRSAC,MREG,ISO,IPOL,PTDATA,JEOF,JST)
      IF(MREG-KREG) 2,3,2
    2 IF(ICK) 1,1,1000
    3 ICK = 1
      DO 4 N=1,8
    4 PODATA(ISO,IPOL,N) = PODATA(ISO,IPOL,N) + PTDATA(N)
      GO TO 1
 1000 CONTINUE
      RETURN
      END
      SUBROUTINE AINPUT(ICTR,JST)
C
C     THIS SUBROUTINE ACCUMULATES DATA FOR AN AGGREGATE REGION FOR OUT.
C
C     THIS SUBROUTINE READS DATA FROM MASTER FILE TO BE USED IN
C     AGGREGATE REGION REPORT (REGION=KREG)
C
```

```
C     ICTR=8 END OF AGG REG.  ICTR=9 END OF RUN   ICTR=7 END OF REG.
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG,IOPT(10)
      DIMENSION PODATA(34,9,8),NARE(5),JREG(305),PTDATA(8)
      KTYPE = 2
      DO 10 I=1,34
      DO 10 J=1,9
      DO 10 K=1,8
      PODATA(I,J,K) = 0.0
   10 CONTINUE
    1 CALL READ(ICTR,MRSAC,MREG,ISO,IPOL,PTDATA,JEOF,JST)
      IF(ICTR  ) 2,2,1000
    2 ITREG = JREG(MREG)
      IF(ITREG-KREG) 1,3,100
    3 DO 4 N=1,8
      PODATA(ISO,IPOL,N) = PODATA(ISO,IPOL,N) + PTDATA(N)
    4 CONTINUE
      GO TO 1
  100 IF(IOPT(10)) 1,1,101
  101 JST = -1
 1000 CONTINUE
      RETURN
      END
      SUBROUTINE SINPUT(ILOC,ICTR,JST)
C
C     THIS SUBROUTINE ACCUMULATES DATA FOR A STATE FOR OUTPUT
C
C     STATE REPORT  - ILOC CONTAINS STATE CODE (A2)
C
C     ICTR=8 END OF AGG REG.  ICTR=9 END OF RUN   ICTR=7 END OF REG.
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG
      DIMENSION PODATA(34,9,8),NARE(5),JREG(305),PTDATA(8)
      KTYPE = 4
      DO 10 I=1,34
      DO 10 J=1,9
      DO 10 K=1,8
      PODATA(I,J,K) = 0.0
   10 CONTINUE
    1 CALL READ(ICTR,MRSAC,MREG,ISO,IPOL,PTDATA,JEOF,JST)
      IF(ICTR-8) 2,1000,1000
    2 IF(MRSAC-ILOC) 1,3,1000
    3 DO 4 N=1,8
      PODATA(ISO,IPOL,N) = PODATA(ISO,IPOL,N) + PTDATA(N)
    4 CONTINUE
      GO TO 1
 1000 CONTINUE
      JST = -1
      RETURN
      END
      SUBROUTINE TINPUT
C
C     THIS SUBROUTINE ACCUMULATES DATA FOR THE GRAND TOTAL (ALL DATA)
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG
      DIMENSION PODATA(34,9,8),NARE(5),JREG(305),PTDATA(8)
      KTYPE = 3
      DO 10 I=1,34
      DO 10 J=1,9
      DO 10 K=1,8
   10 PODATA(I,J,K) = 0.0
    1 JST = 1
      CALL READ(ICTR,MRSAC,MREG,ISO,IPOL,PTDATA,JEOF,JST)
      IF(ICTR-9) 2,3,3
    2 DO 20 N=1,8
   20 PODATA(ISO,IPOL,N) = PODATA(ISO,IPOL,N) + PTDATA(N)
      GO TO 1
    3 CONTINUE
      RETURN
      END
      SUBROUTINE READ(ICTR,MRSAC,MREG,ISO,IPOL,PTDATA,JEOF,JST)
C
C     JEOF IS END OF FILE INDICATOR   =0 NONE SENSED, =1 EOF SENSED
C
C         JST = 0 START (REWIND OF TAPE IF REQUIRED)
C         JST = 1 READ DATA
C         JST = -1 USE LAST DATA POINT (FIRST OF NEW GROUP(REGION ETC) )
C
C     PTEM(5,8) IS TEMP STORAGE OF PTDATA
C
C       RSAC CODE , SOURCE CODE , POLLUTANT CODE  (COLS. 2 THRU 9 )
C
C
C    **************** O P T I O N ************************************
C
C         AN 8 IN COL ONE SEPARATES SOURCES
C         A 9 IN COL ONE INDICATES END OF ALL DATA
C
C    *****************************************************************
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG,IOPT(10)
      DIMENSION PTDATA(8),PTEM(5,8),ICTRT(5),MREGT(5),ISOT(5),IPOLT(5)
      DIMENSION MRSA(5)
  600 CONTINUE
      IF(IOPT(10)) 10,10,500
  500 CONTINUE
      IF(JST) 9,510,511
  510 ISO = 1
      IPOL = 1
      JEOF = 0
      GO TO 9
  511 CONTINUE
      JEOF = 0
      READ 501,ICTR,MRSAC,ISO,IPOL,MREG,(PTDATA(N),N=1,4)
  501 FORMAT(I1,A2,3X,I2,I1,I3,4F11.2)
      JST = 1
      IF(ICTR-8) 503,502,502
  502 JEOF = 1
      ISO = 1
      IPOL = 1
      MREG = 1
      RETURN
  503 CONTINUE
      GO TO 9
   10 CONTINUE
      IF(JST) 9,1,5
    1 JCTR = 5
      REWIND 11
      READ(11,101,ERR=3,END=3) ICTR,MREG,MRSAC,ISO,IPOL,
     1      (PTDATA(N),N=1,8)
  101 FORMAT(  I1,A2,3X,I2,I1,I3,4F11.2  )
    2 CONTINUE
      IF(ICTR    -9) 4,3,3
    3 JEOF = 1
      JCTR = 5
      REWIND 11
      RETURN
    4 CONTINUE
      JCTR = 5
      JEOF = 0
      REWIND 11
      RETURN
    5 CONTINUE
      READ(11,101,ERR=3,END=3) ICTR,MREG,MRSAC,ISO,IPOL,
     1      (PTDATA(N),N=1,8)
      IF(ICTR-8) 9,9,3
    9 CONTINUE
      JST = 1
      IF(MREG) 504,504,505
  504 MREG = 1
  505 CONTINUE
      IF(ISO-34) 507,507,506
  506 ISO = 21
  507 CONTINUE
      IF(ISO) 600,600,508
  508 CONTINUE
      IF(IPOL) 600,600,509
  509 CONTINUE
      RETURN
      END
      SUBROUTINE OUTBO(GROWTH,GROWP)
C
C     THIS SUBROUTINE APPLIES THE YEARLY GROWTH FRACTIONS TO THE
C        ACCUMULATED DATA - THEN WRITES IT OUT ON TAPE FOR NEXT PROGRAM
C
      COMMON KTYPE,KREG,PODATA,POP,NARE,JREG
      DIMENSION PODATA(34,9,8),NARE(5),JREG(305)
      DIMENSION GROWTH(34),GROWP(34)
      DO 10 I=1,2
      IK = I + 2
      II = I + 4
      IJ = I + 6
      DO 10 J=1,34
      DO 10 K=1,9
      PODATA(J,K,IJ) = GROWP(J) * PODATA(J,K,IK)
   10 PODATA(J,K,II) = GROWTH(J)*PODATA(J,K,I)
      WRITE(12,ERR=2,END=1) KTYPE,KREG,PODATA,POP,NARE
      GO TO 3
    1 PRINT 101
  101 FORMAT(12H  ** EOT **                )
      GO TO 3
    2 PRINT 102
  102 FORMAT(20H  * WRITE PARITY *          )
    3 CONTINUE
      PRINT 103,KTYPE,KREG
  103 FORMAT(10X,20HOUTPUT RECORD  TYPE=  ,I3,9H  REGION=  ,I5)
      RETURN
      END

***  TYPICAL RUN CONTROL DECK  ***

11111111111111111111111111111111111111112222222222222222222222222222222222222222
22222222222222222222222222222222222222222222222222222222222222222222222222222222
22222222222222222222222222222222222222222222222222222222222222222222222222222222
22222222222222222222222222222222222222222222222222222222222222223
     1    11     7      CONNECTICUT                CT     7
     2    12    20      MAINE                      ME    20
     3    13    22      MASSACHUSETTS              MA    22
     4    14    30      NEW HAMPSHIRE              NH    30
     5    15    31      NEW JERSEY                 NJ    31
     6    16    33      NEW YORK                   NY    33
     7    17    40      RHODE ISLAND               RI    41
     8    18    46      VERMONT                    VT    47
     9    19    52      PUERTO RICO                PR    40
    10    1A    53      VIRGIN ISLANDS             VI    49
    11    21     8      DELAWARE                   DL     8
    12    22     9      DISTRICT OF COLUMBIA       DC     9
    13    23    18      KENTUCKY                   KY    18
    14    24    21      MARYLAND                   MD    21
    15    25    36      OHIO                       OH    36
    16    26    39      PENNSYLVANIA               PA    39
    17    27    47      VIRGINIA                   VA    48
    18    28    49      WEST VIRGINIA              WV    51
    19    31     1      ALABAMA                    AL     1
    20    32    10      FLORIDA                    FL    10
    21    33    11      GEORGIA                    GA    11
    22    34    25      MISSISSIPPI                MS    25
    23    35    34      NORTH CAROLINA             NC    34
    24    36    41      SOUTH CAROLINA             SC    42
    25    37    43      TENNESSEE                  TN    44
    27    41    14      ILLINOIS                   IL    14
    28    42    15      INDIANA                    IN    15
    29    43    23      MICHIGAN                   MI    23
    30    44    24      MINNESOTA                  MN    24
    31    45    50      WISCONSIN                  WS    52
    32    51     4      ARKANSAS                   AK     4
    33    52    19      LOUISIANA                  LA    19
    34    53    32      NEW MEXICO                 NM    32
    35    54    37      OKLAHOMA                   OK    37
    36    55    44      TEXAS                      TX    45
    37    61     6      COLORADO                   CO     6
    38    62    16      IOWA                       IA    16
    39    63    17      KANSAS                     KA    17
    40    64    26      MISSOURI                   MO    26
    41    65    28      NEBRASKA                   NB    28
    42    66    35      NORTH DAKOTA               ND    35
    43    67    42      SOUTH DAKOTA               SD    43
    44    68    51      WYOMING                    WY    53
    45    71     3      ARIZONA                    AZ     3
    46    72     5      CALIFORNIA                 CF     5
    47    73    12      HAWAII                     HW    12
    48    74    29      NEVADA                     NV    29
    49    75    45      UTAH                       UT    46
    52    81     2      ALASKA                     AA     2
```

```
   53  82   13      IDAHO                 ID   13
   54  83   27      MONTANA               MT   27
   55  84   38      OREGON                OR   38
   56  85   48      WASHINGTON            WN   50
                    AGG. REGION ONE
                    AGG. REGION TWO
                    AGG. REGION THREE
                    AGG. REGION FOUR
                    AGG. REGION FIVE
                    AGG. REGION SIX
                    AGG. REGION SEVEN
                    AGG. REGION EIGHT
                    AGG. REGION NINE
         1 N/ASSIG
          .043                .045 .042 .040      .051 .053 .028 .041 .020
     .047 .032 .027 .032 .032 .051 .066           .049 .015
1              .044 .002 .041 .014
     .    .043 .    .    .    .045 .039 .036 .    .049 .051 .026 .031 .020
     .047 .032 .027 .015 .028 .042 .061 .    .    .047 .011 .    .    .
1    .    .    .058 .013 .056 .026 .061 .061 .061 .061 .    .
            1           COMMENTS AFTER COL 24         AGGREGATE RUN ONLY
```

### 2. Program Listing for Program PRINT

```
C
C     A P C O PRINT PROGRAM
C
C
C     THIS PROGRAM COMPUTES GROWTH,IMPLEMENTATION ANB PRINTS RESULTS
C          FROM THE OUTPUT OF PROGRAM SEARCH
C
C     CONTROL CARD OPTIONS
C
C         COL 16 = 1 - PROVIDE IMPLEMENTATION ON AQCR LEVEL
C         COL 17 = 1 - DROP COST SUMMARY LINE
C         COL 18 = 1 - DROP IMPLEMENTATION PRINTOUT
C         COL 19 = 1 - DROP POLLUTANT PRINTOUT
C         COL 20 = 1 - DROP SOURCE PRINTOUT
C
C     SUBROUTINES -
C        NAME - READS IN NAMES OF SOURCES,PULLUTANTS
C        INPL - READS IN IMPLEMENTATION TIME PERIODS AND IMPLEMENTATION
C                                                        SCHEMES
C         OUTBI - READ IN OF DATA RECORD FROM SEARCH
C        HDG - PRINTAPPROPRATE HEADING
C        PRINT - PRINT OF SOURCES,POLLUTANTS, AND IMPLEMENTATION
C
      COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
      DIMENSION TPER(34),IMPN(10),ISOUR(34,4),IPOLU(9,2),
     1  TOUT(8),OUT(8),PODATA(34,9,8),IOPT(10)
      DIMENSION NARE(5)
      JIDENT = 0
      POPULA = 0.0
      CALL NAME(ISOUR,IPOLU,NSOU)
      CALL IMPL(TPER,TSTART,TSTOP,IMPN)
      READ 101,(IOPT(N),N=1,10)
  101 FORMAT(10X,10I1)
      PRINT 125,(IOPT(JJ),JJ=1,10)
  125 FORMAT(10H  ** CODES       ,10I5)
    1 CONTINUE
      CALL OUTBI(IEO)
      IF(IEO) 11,11,1000
   11 CONTINUE
      CALL HDG
      CALL         PRINT(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
      GO TO 1
 1000 CONTINUE
      STOP
      END
      SUBROUTINE NAME(ISOUR,IPOLU,NSOU)
C
C     THIS SUBROUTINE READS SOURCE NAMES (16 CHARACTERS MAX) AND
C               POLUTANT NAMES (8 CHARACTERS MAX)
      DIMENSION ISOUR(34,4),IPOLU(9,2)
      NSOU = 1
    1 READ 101,ICTR,(ISOUR(NSOU,N),N=1,4)
  101 FORMAT(I10,4A4)
```

```
      NSOU = NSOU + 1
      IF(ICTR-1) 1,1,2
    2 NSOU = NSOU - 1
      DO 3 J=1,9
      READ 102,ICTR,(IPOLU(J,N),N=1,2)
  102 FORMAT (I10,2A4)
      IF(ICTR-2) 3,4,4
    3 CONTINUE
    4 CONTINUE
      RETURN
      END
      SUBROUTINE IMPL(TPER,TSTART,TSTOP,IMPN)
C
C     THIS SUBROUTINE SETS UP IMPLEMENTATION SCHEMES FOR EACH SOURCE
C
C     TSTART = YEAR TO START IMPLEMENTATION  (TYP = 1971)
C     TSTYP  = YEAR TO STOP IMPLEMENTATION   (TYP = 1976)
C     PER    = PERCENT IMP. FOR LESS THAN COMPLETE IMP
C     FIRST CARD IS TYPICAL IMPLEMENTATION SCHEME WITH SPECIFIC
C     SCHEMES FOLLOWING
C
C     STOP BY 1 IN COLUMN 1 OF LAST IMPL. CARD
C
      DIMENSION TPER(34),IMPN(10)
      READ 105,(IMPN(N),N=1,10)
  105 FORMAT(10A4)
      READ 101,ICTR,TSTART,TSTOP,PER
  101 FORMAT(I1,F9.0,F10.0,F10.0)
      DO 1 N=1,34
    1 TPER(N) = PER
    2 IF(ICTR) 3,3,1000
    3 READ 102,ICTR,ISOU,PER
  102 FORMAT(I1,I2,17X,F10.0)
      TPER(ISOU) = PER
      GO TO 2
 1000 CONTINUE
      RETURN
      END
      SUBROUTINE PRINT(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
C
C     THIS SUBROUTINE CONTROLLES THE PRINT SUBS. TO BE USED
C
      COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
      DIMENSION TPER(34),IMPN(10),ISOUR(34,4),IPOLU(9,2),
     1  TOUT(8),OUT(8),PODATA(34,9,8),IOPT(10)
      DIMENSION NARE(5)
      TDIF = TSTOP-1966.5
      DO 20 I=1,34
      DO 20 J=1,9
      DO 20 K=5,8
   20 PODATA(I,J,K) = TDIF*PODATA(I,J,K)
      ISTOP = TSTOP
      PRINT 101,ISTOP
  101 FORMAT(28X,46H     ................. 1967 ...................
     1 28H     ............... GROWTH TO,I5,15H ............   ,/)
      PRINT 102
  102 FORMAT(32X,2(44HINVESTMENT   ANNUAL   UN-CONT.  CONTROLLED
     1  )  )
```

```
      PRINT 103
  103 FORMAT(4X,6HSOURCE,10X, 9HPOLLUTANT,3X,
     1 2(44H   COSTS       COSTS   EMISSIONS  EMISSIONS            ),/,32X,
     2 2(44H  ( 000)      ( 000)   (TONS/YR)  (TONS/YR)            ),/)
C
C     OUTPUT BY SOURCE AND BY PARTICULATE
C
      IF(IOPT(10)) 10,10,11
   10 CONTINUE
      CALL        SOURCE(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
   11 CONTINUE
C
C     THIS ENDS SOURCE BY SOURCE OUTPUT  - START  PART BY PART OUTPUT
C
      IF(IOPT( 9)) 12,12,121
  121 IF(IOPT(7)) 12,12,13
   12 CONTINUE
      CALL         POLUT(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
   13 CONTINUE
C
C     END OF POLUTANT PRINTOUT      IMPLEMENTATION NEXT
C
      IF(IOPT( 8)) 14,14,15
   14 CONTINUE
      CALL         IMPLI(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
   15 CONTINUE
      RETURN
      END
      SUBROUTINE SOURCE(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
C
C     SOURCE BY SOURCE PRINTOUT
C
      COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
      DIMENSION TPER(34),IMPN(10),ISOUR(34,4),IPOLU(9,2),
     1  TOUT(8),OUT(8),PODATA(34,9,8),IOPT(10)
      DIMENSION NARE(5)
      DO 270 I=1,34
      DO 255 J=1,8
      TOUT(J) = 0.0
      OUT(J) = 0.0
  255 CONTINUE
      M=0
C     OUT(8) IS SOURCE OUTPUT TO PRINT STMT
C
      DO 258 K=1,9
      DO 256 J=1,8
  256 OUT(J) = OUT(J) + PODATA(I,K,J)
      IF(PODATA(I,K,3) ) 258,258,257
  257 M = M + 1
  258 CONTINUE
      IF(M-1) 270,260,265
  260 DO 261 K=1,9
      IF(PODATA(I,K,3)) 261,261,262
  261 CONTINUE
  262 CONTINUE
```

```
      PRINT 880,(ISOUR(I,M),M=1,4),(IPOLU(K,M),M=1,2),(OUT(M),M=1,8)
  880 FORMAT(/,2X,4A4,2X,2A4,2X,8F11.1)
      GO TO 270
  265 PRINT 881,(ISOUR(I,M),M=1,4),(OUT(M),M=1,8)
  881 FORMAT(/,2X,4A4,12X,8F11.1)
      DO 267 K=1,9
      IF(PODATA(I,K,3)) 267,267,266
  266 PRINT 882,(IPOLU(K,M),M=1,2),(PODATA(I,K,M),M=3,4),
     1  (PODATA(I,K,M),M=7,8)
  882 FORMAT(20X,2A4,2X,22X,2F11.1,22X,2F11.1)
  267 CONTINUE
  270 CONTINUE
      RETURN
      END
      SUBROUTINE  POLUT(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
C
C     POLLUTANT BY POLLUTANT PRINT
C
      SET COMMON(=17200)
      COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
      DIMENSION TPER(34),IMPN(10),ISOUR(34,4),IPOLU(9,2),
     1  TOUT(8),OUT(8),PODATA(34,9,8),IOPT(10)
      DIMENSION NARE(5)
      IF(IOPT(9)) 1,1,2
    1 PRINT 888
  888 FORMAT(// )
    2 DO 280 K=1,9
      DO 271 J=1,8
  271 OUT(J) = 0.0
      DO 272 I=1,34
      DO 272 J=1,8
      TOUT(J) = TOUT(J) + PODATA(I,K,J)
  272 OUT(J) = OUT(J) + PODATA(I,K,J)
      IF(OUT(1)) 280,280,281
  281 IF(IOPT(9)) 273,273,280
  273 CONTINUE
      PRINT 883,(IPOLU(K,M),M=1,2),(OUT(M),M=3,4) ,(OUT(M),M=7,8)
  883 FORMAT(13X, 7H TOTAL ,2A4,4X,22X,2F11.1,22X,2F11.1)
  280 CONTINUE
      PRINT 884,(TOUT(M),M=1,2),(TOUT(M),M=5,6)
  884 FORMAT(///,30H TOTAL ALL SOURCES ALL POLLUT.  ,2F11.1,6X,3HN/A,
     1  8X,3HN/A,2X,2F11.1,6X,3HN/A,8X,3HN/A)
      RETURN
      END
      SUBROUTINE  IMPLT(TPER,IMPN,ISOUR,IPOLU,TOUT,OUT,
     1 TSTART,TSTOP,IOPT)
C
C     PRINT OF IMPLEMENTATION
C
      COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
      DIMENSION TPER(34),IMPN(10),ISOUR(34,4),IPOLU(9,2),
     1  TOUT(8),OUT(8),PODATA(34,9,8),IOPT(10)
      DIMENSION NARE(5)
      DIMENSION POO(2),POP(2)
C     OUT (N) IS IMPLEMENTATION OUTPUT   OUT(2) AND OUT(4) ARE ACCUM.
C     TOUT(N) IS TOTAL IMPL. COSTS
C
      DO 500 J=1,34
```

```
C      NO ANNUAL INCREASE - NOW
C
       TPERP = TPER(J) / (TSTOP-TSTART+1.0)
       DO 155 N=1,8
       TOUT(N) = 0.0
   155 OUT(N) = 0.0
       POP(1) = 0.0
       POO(1) = 0.0
C
C
       PERAL = 1.0/(TSTOP-TSTART+1.0)
       ISTART = TSTART
       ISTOP = TSTOP
       DO 156 K=1,9
       POO(1) = POO(1) + PODATA(J,K,3)
       POP(1) = POP(1) + PODATA(J,K,4)
       OUT(1) = OUT(1) + PODATA(J,K,1) * PERAL
       OUT(2) = OUT(2) + PODATA(J,K,2) * PERAL
       OUT(3) = OUT(3) + PODATA(J,K,1) * TPERP
       OUT(4) = OUT(4) + PODATA(J,K,2) * TPERP
   156 CONTINUE
       IF(OUT(1)+OUT(2)) 500,500,5
     5 CALL HDG
       PRINT 666,(ISOUR(J,N),N=1,4)
   666 FORMAT(//,10X,8HSOURCE- 4A4)
       PRINT 888
   888 FORMAT(///)
       PRINT 106,(IMPN(N),N=1,10),TPER(J)
   106 FORMAT(25X,55H.. ................. IMPLEMENTATION .................
      1..  ,//,23X,20H FULL IMPLEMENTATION,10X,10A4,2H (,F5.2,2H )//)
       PRINT 101
   101 FORMAT(  13X,       2(12H  INV COSTS ,4X,12HANNUAL COSTS,2X,16HPOLL
      1UTANT LEVEL      ,6X),/,7H   YEAR,6X, 2(4X,6H( 000),9X,6H( 000),
      2 8X,9H(TONS/YR),10X) ,/ )
       PRINT 300
   300 FORMAT(108X,11H(1967 BASE)      )
C
C
C      IMPLEMENTATION SCHEME BASED ON 1967 AND 1975 INCREASES TO CONTINUE
C
       POO(2) = POO(1)
       POP(1) = POP(1) - POO(1)
       POP(2) = POP(1) * TPERP
       POP(1) = POP(1) * PERAL
       DO 150 IDATE=ISTART,ISTOP
C
C      CINCR = FRACTION INCREASE PER YEAR
C           COST = (DATE - 1967) * CINTR * (COST (INI OR ANN),1967)
C
       TDATE = IDATE
       OUT(5) = OUT(5) + OUT(1)
       OUT(6) = OUT(6) + OUT(2)
       POO(1) = POO(1) + POP(1)
       POO(2) = POO(2) + POP(2)
       OUT(7) = OUT(7) + OUT(3)
       OUT(8) = OUT(8) + OUT(4)
       TOUT(1) = TOUT(1) + OUT(5)
       TOUT(3) = TOUT(3) + OUT(7)
       PRINT 107,IDATE,OUT(5),OUT(6),POO(1),OUT(7),OUT(8),POO(2)
```

```
  107 FORMAT(I7,3F16.1,4X,3F16.1)
      OUT(5) = 0.0
      OUT(7) = 0.0
  150 CONTINUE
      TOUT(2) = OUT(6)
      TOUT(4) = OUT(8)
      PRINT 108,TOUT(1),TOUT(2),POO(1),TOUT(3),TOUT(4),POO(2)
  108 FORMAT(/,1X,6H TOTAL,3F16.1,4X,3F16.1,/ )
C
C     END OF 1967 BASE IMPLEMENTATION SCHEMES
C
      PRINT 301
  301 FORMAT(108X,11H(GROWTH)          )
      DO 255 N=1,4
      OUT(N) = 0.0
      TOUT(N) = 0.0
  255 CONTINUE
      POO(1) = 0.0
      POP(1) = 0.0
      DO 256 K=1,9
      OUT(1) = OUT(1) + PODATA(J,K,5) * PERAL
      OUT(2) = OUT(2) + PODATA(J,K,6) * PERAL
      OUT(3) = OUT(3) + PODATA(J,K,5) * TPERP
      OUT(4) = OUT(4) + PODATA(J,K,6) * TPERP
      POO(1) = POO(1) + PODATA(J,K,7)
      POP(1) = POP(1) + PODATA(J,K,8)
  256 CONTINUE
      POO(2) = POO(1)
      POP(1) = POP(1) - POO(1)
      POP(2) = POP(1) * TPERP
      POP(1) = POP(1) * PERAL
      DO 355 N=5,8
      OUT(N) = 0.0
  355 CONTINUE
      DO 250 IDATE = ISTART,ISTOP
      POO(1) = POO(1) + POP(1)
      POO(2) = POO(2) + POP(2)
      OUT(5) = OUT(5) + OUT(1)
      OUT(6) = OUT(6) + OUT(2)
      OUT(7) = OUT(7) + OUT(3)
      OUT(8) = OUT(8) + OUT(4)
      TOUT(1) = TOUT(1) + OUT(5)
      TOUT(3) = TOUT(3) + OUT(7)
      PRINT 107,IDATE,OUT(5),OUT(6),POO(1),OUT(7),OUT(8),POO(2)
      OUT(5) = 0.0
      OUT(7) = 0.0
  250 CONTINUE
      TOUT(2) = OUT(6)
      TOUT(4) = OUT(8)
      PRINT 108,TOUT(1),TOUT(2),POO(1),TOUT(3),TOUT(4),P80(2)
  500 CONTINUE
C
C     END OF GROWTH IMPLEMENTATION SCHEMES
C
      RETURN
      END
      SUBROUTINE HDG
C
C     THIS SUBROUTINE PRINTS APPROPRATE HEADING FOR SUMMARY LEVEL SPEC.
```

```
C
C
C      KTYPE KEY VALUES -
C                1 = INBIVIDUAL REGION (1-305)
C                2 = AGGREGATE REGION (1-9)
C                3 = TOTAL
C                4 = STATE
C
       COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
       DIMENSION PODATA(34,9,8)
       DIMENSION NARE(5)
       PRINT 105
   105 FORMAT(1H-,29X,45HNATIONAL AIR POLLUTION CONTROL ABMINISTRATION   ,
      1//,44X,17HPOLLUTION REPORT ,/)
       IF(KTYPE-2) 1,2,3
     1 PRINT 501,KREG
   501 FORMAT(32X,36HLOBAL NAPCA REGION REPORT , REGION = ,I5,/ )
       RETURN
     2 PRINT 502,KREG
   502 FORMAT(29X,40H * AGGREGATE NAPCA CONTROL REGION NUMBER,I3,3H * ,/)
       PRINT 505,(NARE(N),N=1,5)
   505 FORMAT(41X,5A4,/)
       RETURN
     3 IF(KTYPE-4) 5,4,4
     4 PRINT 504,(NARE(N),N=1,5)
   504 FORMAT(40X,22H  ** STATE SUMMARY **          ,//,41X,5A4,/)
       RETURN
     5 PRINT 503
   503 FORMAT(37X,28H  **** NATIONAL SUMMARY ****  ,/ )
       RETURN
       END
       SUBROUTINE OUTBI(IEO)
C
C      THIS SUBROUTINE READS IN POLLUTATION MATRIX,TYPE,REGION,POPULATION
C
       COMMON KTYPE,KREG,PODATA,POPULA,NARE,JIDENT
       DIMENSION PODATA(34,9,8)
       DIMENSION NARE(5)
     1 READ(12,ERR=3,ENB=2) KTYPE,KREG,PODATA,POPULA,NARE
       GO TO 5
     2 PRINT 102
   102 FORMAT(15H  EOF                 )
       GO TO 4
     3 PRINT 103
   103 FORMAT( 20H * PARITY ERROR *              )
     4 REWIND 2
       IEO = 1
       RETURN
     5 CONTINUE
       IEO = 0
       RETURN
       END
```

*** TYPICAL RUN CONTROL DECK ***

```
         1SOLID WASTE
         1STEAM/ELECT PWR
```

```
          1IND. BOILERS
          1COMM/IND HEATING
          1RES HEATING
          1KRAFT PULP IND.
          1IRON AND STEEL
          1GRAY IRON FOUND.
          1NONFERROS META.
          1SULFURIC ACID
          1PHOSPHATE FERT.
          1PETROLEUM REFIN.
          1ASPHALT CEM. IND
          1CEMENT INDUSTRY
          1LIME INDUSTRY
          1COAL CLEANING
          1PET PROD STORAGE
          1GRAIN MILL,HAND.
          1VARNISH INDUSTRY
          1RUBBER INDUSTRY
          1SEC. NONFERROUS
          1PLASTICS IND
          1RENDERING IND.
          1ELEM. PHOSPHORUS
          1BRICK AND TILE
          1      N/A
          1      N/A
          1      N/A
          1      N/A
          1      N/A
          1PRIMARY ALUMINUM
          1PRIMARY COPPER
          1PRIMARY LEAD
          1PRIMARY ZINC
          2
          1 PARTIC.
          1 SOX
          1 HYDROC.
          1 CO
          1 FLOURI.
                 NO+
          1      N/A
          1      N/A
          1      N/A
          2
                FIFTY PERCENT
1     1971       1976    0.50
                     COMMENTS AFTER COL 20               NO SPECIAL RESTRICTIONS
```

## V. SOURCE, POLLUTANT, AND AQCR CODES

This section contains a summary of all source, pollutant, and location codes used in the air pollution data system. The four major sections are: (1) source codes, (2) pollutant codes, (3) state codes, and (4) AQCR/RSAC location codes.

Table W-8 shows the code number assigned to each source. Since code number nine and 26 through 30 have not been assigned, they may be used for expanded source categories.

Table W-9 shows the code numbers assigned to each emission. Since the present computer programs allow up to nine emissions, unused codes six through nine may be used for an expanded list of emissions.

Table W-10 shows the first two digits of the RSAC code for each state (and the District of Columbia) used in the air pollution data system.

Table W-11 shows the data used in the file and as used in program MATCH (section II). The first 298 card images are the AQCR names and the state to which they are assigned, i.e., Birmingham is AQCR number one in state 31 (Alabama). The reaminder of the data file contains an alphanumerical file of counties arranged by RSAC with their corresponding AQCR code.

TABLE W-8. - AIR POLLUTION SOURCE CODES

| Code Number | Source |
|---|---|
| 1 | Solid Waste Disposal |
| 2 | Steam-Electric Power Plants |
| 3 | Industrial Boilers |
| 4 | Commercial-Institutional Heating Plants |
| 5 | Residential Heating Plants |
| 6 | Kraft (Sulfate) Pulp Industry |
| 7 | Iron and Steel Industry |
| 8 | Gray Iron Foundry Industry |
| 9 | (not assigned) |
| 10 | Sulfuric Acid Industry |
| 11 | Phosphate Fertilizer Industry |
| 12 | Petroleum Refinery Industry |
| 13 | Asphalt Cement Industry |
| 14 | Cement Industry |
| 15 | Lime Industry |
| 16 | Coal Cleaning Industry |
| 17 | Petroleum Products and Storage Industry |
| 18 | Grain Milling and Handling Industry |
| 19 | Varnish Industry |
| 20 | Rubber (Tires) Industry |
| 21 | Secondary Nonferrous Metallurgical Industry |
| 22 | Plastics Industry |
| 23 | Rendering Industry |
| 24 | Elemental Phosphorus |
| 25 | Brick and Tile Industry |
| 26-30 | (not assigned) |
| 31 | Primary Aluminum Industry |
| 32 | Primary Copper Industry |
| 33 | Primary Lead Industry |
| 34 | Primary Zinc Industry |

TABLE W-9. - AIR POLLUTION EMISSION CODES

| Code Number | Emission |
|---|---|
| 1 | Particulate |
| 2 | Sulfur Oxides |
| 3 | Hydrocarbons |
| 4 | Carbon Oxides |
| 5 | Fluorides |
| 6-9 | (not assigned) |

TABLE W-10. - LISTING OF STATES AND RSAC LOCATION CODES

| | | | |
|---|---|---|---|
| 31 | ALABAMA | AL | 1 |
| 81 | ALASKA | AA | 2 |
| 71 | ARIZONA | AZ | 3 |
| 51 | ARKANSAS | AK | 4 |
| 72 | CALIFORNIA | CF | 5 |
| 61 | COLORADO | CO | 6 |
| 11 | CONNECTICUT | CT | 7 |
| 21 | DELAWARE | DL | 8 |
| 22 | DISTRICT OF COLUMBIA | DC | 9 |
| 32 | FLORIDA | FL | 10 |
| 33 | GEORGIA | GA | 11 |
| 73 | HAWAII | HW | 12 |
| 82 | IDAHO | ID | 13 |
| 41 | ILLINOIS | IL | 14 |
| 42 | INDIANA | IN | 15 |
| 62 | IOWA | IA | 16 |
| 63 | KANSAS | KA | 17 |
| 23 | KENTUCKY | KY | 18 |
| 52 | LOUISIANA | LA | 19 |
| 12 | MAINE | ME | 20 |
| 24 | MARYLAND | MD | 21 |
| 13 | MASSACHUSETTS | MA | 22 |
| 43 | MICHIGAN | MI | 23 |
| 44 | MINNESOTA | MN | 24 |
| 34 | MISSISSIPPI | MS | 25 |
| 64 | MISSOURI | MO | 26 |
| 83 | MONTANA | MT | 27 |
| 65 | NEBRASKA | NB | 28 |
| 74 | NEVADA | NV | 29 |
| 14 | NEW HAMPSHIRE | NH | 30 |
| 15 | NEW JERSEY | NJ | 31 |
| 53 | NEW MEXICO | NM | 32 |
| 16 | NEW YORK | NY | 33 |
| 35 | NORTH CAROLINA | NC | 34 |
| 66 | NORTH DAKOTA | ND | 35 |
| 25 | OHIO | OH | 36 |
| 54 | OKLAHOMA | OK | 37 |
| 84 | OREGON | OR | 38 |
| 26 | PENNSYLVANIA | PA | 39 |
| 19 | PUERTO RICO | PR | 40 |
| 17 | RHODE ISLAND | RI | 41 |
| 36 | SOUTH CAROLINA | SC | 42 |
| 67 | SOUTH DAKOTA | SD | 43 |
| 37 | TENNESSEE | TN | 44 |
| 55 | TEXAS | TX | 45 |
| 75 | UTAH | UT | 46 |
| 18 | VERMONT | VT | 47 |
| 27 | VIRGINIA | VA | 48 |
| 1A | VIRGIN ISLANDS | VI | 49 |
| 85 | WASHINGTON | WN | 50 |
| 28 | WEST VIRGINIA | WV | 51 |
| 45 | WISCONSIN | WS | 52 |
| 68 | WYOMING | WY | 53 |

TABLE W-11. - LISTING OF AQCR's AND COUNTIES WITHIN AQCR's

| | | | |
|---|---|---|---|
| 1 | 13100 | 6 | BIRMINGHAM |
| 1 | 27100 | 4 | PHOENIX-TUCSON |
| 1 | 33700 | 3 | MEMPHIS |
| 1 | 47200 | 6 | LOS ANGELES |
| 1 | 57200 | 9 | SAN FRANCISCO BAY AREA |
| 1 | 62300 | 3 | LOUISVILLE |
| 1 | 72500 | 9 | CINCINNATI |
| 1 | 84400 | 7 | MINNEAPOLIS-ST. PAUL |
| 1 | 93700 | 4 | CHATTANOOGA |
| 1 | 102600 | 11 | PHILADELPHIA |
| 1 | 112600 | 7 | PITTSBURGH |
| 1 | 125500 | 8 | HOUSTON-GALVESTON |
| 1 | 135500 | 10 | DALLAS-FORT WORTH |
| 1 | 145500 | 3 | SAN ANTONIO |
| 1 | 152200 | 10 | NATIONAL CAPITAL AREA |
| 1 | 168500 | 4 | PUGET SOUND |
| 1 | 174500 | 7 | MILWAUKEE |
| 1 | 181600 | 2 | NIAGARA FRONTIER |
| 1 | 194200 | 8 | STEUBENVILLE-WEIRTON-WHEELING |
| 1 | 202500 | 6 | DAYTON |
| 1 | 212500 | 8 | CLEVELAND |
| 1 | 225400 | 9 | OKLAHOMA CITY |
| 1 | 234200 | 8 | INDIANAPOLIS |
| 1 | 246400 | 9 | KANAS CITY |
| 1 | 252500 | 3 | TOLEDO |
| 1 | 264300 | 4 | DETROIT-PORT HURON |
| 1 | 272400 | 6 | BALTIMORE |
| 1 | 281700 | 7 | PROVIDENCE |
| 1 | 291300 | 4 | BOSTON |
| 1 | 306100 | 5 | DENVER |
| 1 | 311100 | 6 | HARTFORD-SPRINGFIELD-NEW HAVEN |
| 1 | 323200 | 3 | MIAMI |
| 1 | 333300 | 7 | ATLANTA |
| 1 | 344100 | 9 | CHICAGO |
| 1 | 356400 | 7 | ST.LOUIS |
| 1 | 366500 | 7 | OMAHA |
| 1 | 371600 | 19 | NEW YORK-NEW JERSEY-CONNECTICU |
| 1 | 388400 | 12 | PORTLAND |
| 1 | 391800 | 7 | CHAMPLAIN VALLEY |
| 1 | 401A00 | 1 | VIRGIN ISLANDS |
| 1 | 417100 | 8 | COLUMBUS-PHOENIX CITY |
| 1 | 423100 | 15 | MOBILE-PENSACOLA-BILOXI-GULFPO |
| 1 | 433100 | 6 | FLORENCE-CORINTH |
| 1 | 443100 | 3 | SEQUATCHIE RIVER VALLEY |
| 1 | 453100 | 2 | MONTGOMERY |
| 1 | 463100 | 2 | GADSDEN-ANNISTON |
| 1 | 473100 | 4 | HUNTSVILLE |
| 1 | 483100 | 2 | SELMA |
| 1 | 493100 | 2 | DOTHAN |
| 1 | 508100 | 2 | ANCHORAGE |
| 1 | 518100 | 1 | FAIRBANKS |
| 1 | 527100 | 1 | YUMA |
| 1 | 537100 | 1 | FLAGSTAFF |
| 1 | 547100 | 1 | PRESCOTT |

(continued)

```
1 555100 10     FORT SMITH-MUSKOGEE
1 565100 10     TEXARKANA-SHREVEPORT
1 575100  3     LITTLE ROCK
1 585100  1     PINE BLUFF
1 595100  4     EL DORADO
1 605100  2     HOT SPRINGS
1 615100  8     BLYTHEVILLE
1 627200  1     SAN DIEGO
1 637200  5     SACRAMENTO
1 647200  2     STOCKTON
1 657200  2     FRESNO
1 667200  1     BAKERSFIELD
1 677200  3     SALINAS-MONTEREY-SANTA CRUZ
1 687200  1     EUREKA
1 697200  2     MODESTO-MERCED
1 707200  2     EL CENTRO-BRAWLEY
1 717200  2     SAN LUIS OBISPO
1 727200  3     REDDING-RED BLUFF
1 737200  1     CHICO-OROVILLE
1 747200  2     VISALIA
1 754200 12     EVANSVILLE-OWENSBORO-HENBERSON
1 762800  9     HUNTINGTON-ASHLAND-PORTSMOUTH-
1 774100  7     PADUCAH-METROPOLIS-CAIRO
1 782300  4     LEXINGTON
1 792300  2     BOWLING GREEN
1 804400  8     DULUTH-SUPERIOR
1 814500  7     LA CROSSE-WINONA
1 824400  7     ST.CLOUD
1 834400  8     ROCHESTER-AUSTIN-ALBERT-OWATO-
1 844400  5     MANKATO-NEW ULM
1 853400  3     JACKSON
1 863400  3     GREENVILLE
1 873400  1     MERIDIAN
1 883400  2     LAUREL-HATTIESBURG
1 893400  2     NATCHEZ
1 908300  2     BILLINGS
1 918300  2     GREAT FALLS
1 928300  2     BUTTE-ANACONDA
1 938300  1     MISSOULA
1 948300  1     HENENA
1 958300  1     KALISPELL FLATHEAD LAKE
1 968300  1     BOZEMAN
1 973700 14     BRISTOL-JOHNSON CITY-KINGSPORT
1 983700  7     NASHVILLE
1 993700  5     KNOXVILLE
11003700  5     JACKSON
11018400  1     ASTORIO
11028400  1     PENDLETON
11038400  3     GRANTS PASS-MEDFORD
11048400  1     KLAMATH
11052600  5     ALLENTOWN-EASTON-PHILLIPSBURG
11062600  4     BINGHAMTON
11072600  4     JOHNSTOWN-ALTOONA
11082600  3     SCRANTON-WILKES BARRE-HAZELTON
11092600  4     HARRISBURG-LEBANON
11102600  1     READING
11112600  2     YORK
11122600  1     LANCASTER
11132600  5     WILLIAMSPORT-SUNBURY
```

(continued)

| | | |
|---|---|---|
| 11143600 | 6 | CHARLOTTE |
| 11153600 | 3 | CHARLESTON |
| 11163600 | 2 | COLUMBIA |
| 11173600 | 4 | GREENVILLE-SPARTANBURG-ANDERSO |
| 11183600 | 9 | FLORENCE |
| 11196700 | 3 | SIOUX FALLS |
| 11206700 | 3 | RAPID CITY |
| 11216700 | 1 | ABERDEEN |
| 11225500 | 2 | AMARILLO |
| 11235500 | 2 | WICHITA FALLS |
| 11245500 | 2 | MIDLAND-ODESSA |
| 11255500 | 2 | ABILENE |
| 11265500 | 1 | SAN ANGELE |
| 11275500 | 1 | TYLER |
| 11285500 | 1 | SHERMAN-DENISON |
| 11295500 | 1 | WACO-TEMPLE-KILLEN |
| 11305500 | 1 | AUSTIN |
| 11315500 | 2 | LAREDO-EAGLE PASS |
| 11325500 | 2 | LOWER RIO GRANDE VALLEY |
| 11335500 | 5 | CORPUS CHRISTI |
| 11345500 | 1 | LUBBOCK |
| 11355500 | 1 | VICTORIA |
| 11365500 | 1 | BRYAN |
| 11375500 | 1 | BIG SPRING |
| 11385500 | 4 | LUFKIN-NACOGBOCHES |
| 11397500 | 15 | FOUR CORNERS |
| 11407500 | 4 | WASATCH FRONT(SALT LAKE CITY) |
| 11417500 | 2 | LOGAN |
| 11421800 | 1 | MONTPELIER-BARRE |
| 11432700 | 7 | RICHMOND-PETERSBURG |
| 11442700 | 3 | LYNCHBURG |
| 11452700 | 9 | ROANOKE-RADFORD-PULASKI |
| 11462700 | 8 | CHARLOTTSVILLE |
| 11472700 | 10 | DAVILLE |
| 11482700 | 5 | SHENANDOAH VALLEY |
| 11498500 | 2 | SPOKANE-COERBDALENE |
| 11508500 | 2 | BELLINGHAM |
| 11518500 | 2 | YAKIMA |
| 11528500 | 2 | RICHLAND-KENNEWICK-PASCO |
| 11538500 | 1 | WALLA WALLA |
| 11548500 | 1 | ABERDEEN-HOQUIAM |
| 11552800 | 4 | CUMBERLAND-KEYSER |
| 11562800 | 2 | CHARLESTON |
| 11572800 | 3 | CLARKSBURG-FAIRMONT-MORGANTOWN |
| 11582800 | 4 | BLUEFIELD-PRINCETON |
| 11594500 | 6 | MENOMINEE-ESCANABA-MARINETTE |
| 11604500 | 3 | MADISON |
| 11614500 | 5 | GREEN BAY-FOND DU LAC |
| 11624500 | 4 | MAMITOWOC-SHEBOYGAN |
| 11634500 | 4 | EAU CLAIRE |
| 11644500 | 5 | WAUSAU |
| 11656800 | 2 | CHEYENNE |
| 11666800 | 2 | CASPER |
| 11673500 | 11 | NORFOLK-ELIZABETH CITY |
| 11683500 | 1 | ASHEVILLE |
| 11693500 | 7 | WINSTON-SALEM-GREENSBORO+HIGH |
| 11703500 | 4 | RALEIGH-DURHAM |
| 11713500 | 1 | FAYETTEVILLE |
| 11723500 | 2 | WILMINGTON |

(continued)

| | | |
|---|---|---|
| 11733500 | 8 | ROCKY-MOUNT-GOLDSBORO-KINGSTON |
| 11746600 | 2 | FARGO-MOORHEAD |
| 11756600 | 2 | BISMARK-MANDAN |
| 11766600 | 1 | MINOT |
| 11776600 | 2 | GRAND FORKS |
| 11785500 | 2 | EL PASO |
| 11795300 | 3 | DOUGLAS-LORDSBURG |
| 11805300 | 4 | ALBUQUERQUE |
| 11815300 | 1 | SANTA FE |
| 11825300 | 3 | ROSWELL-CARISBED-HOBBS(PECOS) |
| 11835300 | 1 | ALAMOGORDO |
| 11845300 | 1 | CLOVIS |
| 11851600 | 5 | ROCHESTER |
| 11861600 | 4 | SYRACUSE-AUBURN |
| 11871600 | 2 | UTICA-ROME |
| 11881600 | 4 | ALBANY-SCHNECTADY-TROY-AMSTERD |
| 11891600 | 3 | WATERTOWN |
| 11901600 | 3 | ELMIRA-CORNING-ITHACA |
| 11911600 | 6 | NEWBURGH-POUGHKEEPSIE-KINGSTON |
| 11921600 | 2 | JAMESTOWN |
| 11932500 | 6 | YOUNGSTOWN-ERIE |
| 11942500 | 8 | PARKERSBURG-MARIETTA |
| 11952500 | 2 | LIMA-FINDLAY |
| 11962500 | 6 | COLUMBUS-NEWARK |
| 11972500 | 2 | MANSFIELD |
| 11982500 | 5 | ZANESVILLE-CAMBRIDGE |
| 11992500 | 6 | MARION |
| 12002500 | 5 | SANDUSKY |
| 12015400 | 3 | TULSA |
| 12025400 | 1 | LAWTON |
| 12035400 | 1 | ENID |
| 12044200 | 8 | SOUTH BEND-ELKHART-BENTON HARB |
| 12054200 | 2 | MUNCIE-ANDERSON |
| 12064200 | 4 | TERRE HAUTE |
| 12074200 | 1 | FORT WAYNE |
| 12084200 | 2 | LAFAYETTE |
| 12094200 | 8 | KOKOMO-MARION |
| 12104200 | 3 | BLOOMINGTON |
| 12114200 | 4 | RICHMOND |
| 12126200 | 5 | DAVENPORT-ROCK ISLAND-MOLINE |
| 12136200 | 4 | DUBUQUE |
| 12146200 | 4 | KEOKUK |
| 12156200 | 2 | DES MOINES -AMES |
| 12166200 | 6 | WATERLOO |
| 12176200 | 2 | CEDAR RAPIDS-IOWA CITY |
| 12186200 | 5 | FORT DODGE |
| 12196200 | 2 | OTTUMUA |
| 12206200 | 2 | MASON CITY |
| 12216300 | 3 | WICHITA |
| 12226300 | 3 | TOPEKA-LAWRENCE |
| 12236300 | 1 | HUTCHINSON |
| 12246300 | 1 | SALINA |
| 12254300 | 3 | GRAND RAPIDS-MUSKEGON |
| 12264300 | 3 | LANSING |
| 12274300 | 3 | BAY CITY-SAGINAW-MIDLAND |
| 12284300 | 3 | FLINT |
| 12294300 | 2 | ANN ARBOR-JACKSON |
| 12304300 | 3 | KALAMAZOO-BATTLE CREEK |
| 12314300 | 1 | SAULT STE. MARIE |

(continued)

```
12325200 43                        SOUTHERN LOUISIANA-TEXAS
12335200  8                        NORTHEAST LOUISIANA-VICKSBURG
12341200  4                        PORTLAND-LEWISTON-AUBURN
12351200  3                        BANGOR
12361200  1                        HOULTON-CARIBOU
12371200  2                        AUGUSTA-WATERVILLE-SKOWHEGAN
12382600  4                        HAGARSTOWN
12391300  1                        WORCESTER-FITCHBURG-LEOMINSTER
12401300  1                        PITTSFIELD
12416100  1                        COLORADO SPRINGS
12426100  1                        PUEBLO
12436100  2                        FORT COLLINS
12446100  1                        GRAND JUNCTION
12456100  1                        ALAMOSA
12466100  1                        STERLING
12471100  1                        WATERBURY-TORRINGTON
12481100  1                        NEW LONDON
12491100  1                        WILLIMANTIC
12502100  2                        DOVER (SOUTHERN DELAWARE)
12513200  3                        TAMPA-ST. PETERSBURG-LAKELAND
12523200  6                        ORLANDO
12533200  4                        JACKSONVILLE
12543200  1                        TALLAHASSEE
12553200  3                        FORT MYERS
12563200  2                        SARASOTA
12573200  3                        FORT PIERCE-VERO BEACH
12583200  3                        GAINESVILLE
12593300  3                        AUGUSTA-AIKEN
12603300  3                        SAVANNAH-BEAUFORT
12613300  7                        MACON
12623300  1                        ALBANY
12633300  1                        VALDOSTA
12643300  1                        ATHENS
12653300  3                        ROME
12663300  1                        GAINESVILLE
12673300  1                        BRUNSWICK
12687300  5                        ALL OF HAWAII
12698200  4                        LEWISTON-MOSCOW-CLARKSTON-
12708200  3                        BOISE
12718200  4                        POCATELLO-IDAHO FALLS
12728200  1                        TWIN FALLS
12734100  6                        ROCKFORD-JANESVILLE-BELOIT
12744100  4                        PEORIA
12754100  1                        BLOOMINGTON
12764100  2                        CHAMPAIN-URBANA-DANVILLE
12774100  3                        SPRINGFIELD
12784100  1                        DECATUR
12794100  2                        GALESBURG
12804100  2                        QUINCY
12814100  4                        KANKAKEE
12824100  4                        CARBONDALE-MARION-HARRISBURG
12834100  4                        HENNEPIN-OTTOWA
12844100  2                        CHARLESTON-MATTON
12855400 20                        JOPLIN-N.E.OKL.-FAYETTEVILLE
12866400  2                        SPRINGFIELD
12876400  5                        COLUMBIA-JEFFERSON CITY
12886400  4                        CAPE GIRAVDEAU-CARUTHERSVILLE
12896500  2                        SIOUX CITY
12906500  1                        LINCOLN
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(continued)

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12916500   3                                         GRAND ISLAND
12927400   3                                         LAS VEGAS-KINGMAN
12937400   7                                         RENO-CARSON CITY
12941400   4                                         LAWRENCE-LOWELL-MANCHESTER
12951400   2                                         BERLIN-RUMFORD
12961400   2                                         ROCHESTER-DOVER-PORTSMOUTH
12971500   3                                         ATLANTIC CITY-SOUTHEAST NEW JE
12981900                                             PUERTO RICO
2 371111         745.69     795.00     884.64FAIRFIELD (PART/WHOLE)
2 311121         777.78     823.00     904.36HARTFORD
2 311122         106.25     115.50     132.75MIDDLESEX
2 311123          88.11      99.00     120.32TOLLAND
2 311151         716.97     744.00     791.34NEW HAVEN (WHOLE/PART WATERBU)
22481161         211.75     221.50     238.75NEW LONDON
22471191         134.68     145.00     164.02LITCHFIELD(WHOLE/PART OUT)
224911J2          76.66      82.00      91.74WINDHAM
22341211          89.19      88.00      86.04ANDROSCOGGIN
22341221         191.89     194.00     197.56CUMBERLAND
223612H1         100.01      95.00      87.19AROOSTOOK
223712I1          90.29      91.50      93.54KENNEBEC
223412J3          23.15      23.40      23.80SAGADAHOC
223512K1         128.19     127.00     125.03PENOBSCOT
223412M1         103.49     102.00      99.55YORK
229512R2          43.59      43.00      42.02OXFORD
223712R4          41.34      42.50      44.48SOMERSET
223512S1          32.59      32.00      31.03HANCOCK
223512S2          30.64      29.00      26.44WASHINGTON
2 291311         615.46     641.00     685.96ESSEX (WHOLE/PART LOWELL-LAWR)
2 291312        1342.21    1370.00    1417.60MIDDLESEX (WHOLE/PART LOWELL-)
2 291313         577.25     609.00     665.89NORFOLK (WHOLE/PART PROVIDENCE
2 281314         297.01     321.00     365.45PLYMOUTH (WHOLE/PART IN BOSTON
2 291315         714.00     658.00     658.00SUFFOLK
22401381         147.29     147.00     146.50BERKSHIRE (WHOLE/PART OUT)
2 281391         415.90     432.00     460.24BRISTOL (WHOLE/PART IN BOSTON)
2 3113A1         453.97     460.00     470.22HAMPDEN
2 3113A2         117.46     127.00     144.67HAMPSHIRE
223913B1         610.43     628.00     658.40WORCESTER(PART BOSTON,PART OUT
22961411         116.94     131.70     160.69ROCKINGHAM
22941421         201.81     220.00     254.12HILLSBOURGH
229414H1          74.47      80.00      90.15MERRIMACK
229414R1          31.60      33.50      36.91BELKNAP
229514R3          35.59      35.00      34.02COOS
229614R5          64.98      66.50      69.09STRAFFORD
229414S1          47.43      50.50      56.05CHESHIRE
21051511          69.71      74.00      81.73WARREN
22971521         176.85     186.00     202.32ATLANTIC
2 371531         598.59     595.00     589.05HUDSON
2 371541         942.17     950.00     963.17ESSEX
2 371542         331.60     365.00     428.50MORRIS
2 371543         544.58     550.00     559.14UNION
2 371551         876.50     905.00     954.58BERGEN
2 371552         444.89     457.00     477.91PASSAIC
2 101561         288.48     333.00     423.64BURLINGTON
2 101562         443.67     465.00     502.86CAMDEN
2 101563         158.33     170.00     191.41GLOUCESTER
2 101571         291.83     304.00     325.41MERCER
2 101581          63.95      67.00      72.40SALEM
229715G1          54.63      58.00      64.08CAPE MAY
229715G2         121.59     128.00     139.44CUMBERLAND
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(continued)

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2 3715H1          523.14    570.00    657.83MIDDLESEX
2 3715H2          181.07    199.00    233.01SOMERSET
2 3715I1          412.29    455.00    536.50MONMOUTH
210515R1           62.86     70.00     83.79SUSSEX
210515S1           49.71     68.00    116.36HUNTERDON
21881611          285.77    290.00    297.17ALBANY
21881612          146.97    150.00    155.17RENSSELAER
21881613          101.37    110.00    126.05SARATOGA
21881614          154.19    156.00    159.05SCHNECTADY
21061621          227.19    229.00    232.03BROME
2 181631         1105.97   1115.00   1130.20ERIE
2 181632          245.95    240.00    230.39NIAGARA
2 371641         1479.55   1525.00   1603.89BRONX
2 371642         2643.98   2635.00   2620.08KINGS
2 371643         1430.43   1457.00   1502.37NASSAU
2 371644         1648.82   1575.00   1459.13NEW YORK (MANHATTEN)
2 371645         1988.50   1935.00   1848.98QUEENS
2 371646          272.16    300.00    353.05RICHMOND
2 371647          196.86    225.00    281.47ROCKLAND
2 371648          960.00   1108.00   1300.00SUFFOLK
2 371649          874.91    890.00    915.72WESTCHESTER
21851651          664.77    712.00    798.42MONROE
21861661           59.50     59.50     59.50MADISON
21861662          469.72    480.00    497.62ONONDAGA
21861663           94.50    100.00    109.89OSWEGO
21871671           69.00     69.00     69.00HERKIMER
21871672          276.79    275.00    272.03ONEIDA
219216G1          148.29    148.00    147.50CHAUTAUQUA
219016H1          103.00    103.00    103.00CHEMUNG
219016H2          101.18    103.00    106.09STEUBEN
210616H3           44.55     47.00     51.37TIGOA
2 3916I1           77.33     73.50     67.52CLINTON
219116J1          209.06    232.00    276.12DUTCHESS
219116J2           45.13     54.00     73.03PUTNAM
218516K2           38.36     40.50     44.33ORLEANS
218916L1           88.83     88.60     88.20JEFFERSON
218916L2           24.12     25.10     26.80LEWIS
219116M1          204.52    218.00    242.49ORANGE
218916N1          109.79    111.00    113.03ST. LAWRENCE
219216R2           81.59     82.80     84.84CATTARAUGUS
218616R3           75.65     75.90     76.30CAYUGA
218516R5           48.81     52.50     59.28LIVINGSTONE
218516R6           73.57     76.00     80.22ONTARIO
219016R8           75.65     79.00     84.91TOMPKINS
218516R9           75.34     79.00     85.49WAYNE
2 3916S1           34.83     34.00     32.65ESSEX
219116T2           50.51     52.40     55.69COLUMBIA
219116T4           33.09     33.70     34.73GREENE
219116T8          135.14    140.00    148.48ULSTER
2 281721           41.94     44.22     48.28BRISTOL
2 281722          131.49    141.00    158.43KENT
2 281723           89.71     90.80     92.63NEWPORT
2 281724          570.98    566.50    559.09PROVIDENCE
2 281725           73.67     82.50     99.70WASHINGTON
2 3918G1           84.20     93.50    111.40CHITTENDEN
2 3918H1           48.76     51.20     55.54RUTLAND
21421811           44.25     46.20     49.63WASHINGTON
2 3918R3           29.43     29.20     28.80FRANKLIN
2 3918R4            2.99      3.30      3.89GRAND ISLE
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(continued)

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2 3918S1          21.35    22.70     25.13ADDISON
22981900         500.66             560.81ALL OF PUERTO RICO
2 401A00          36.48     0.00     42.01ALL OF VIRGIN ISLANDS
2 102111         367.56   384.00    413.05NEW CASTLE
225021G1          77.31    86.00    102.75KENT
225021H1          80.59    80.00     79.01SUSSEX
2 152211         858.88   944.50   1107.12DISTRICT OF COLUMBIA
2  72311          90.59    90.00     89.01CAMPBELL
2  72312         126.00   126.00    126.00KENTON
2 752321          34.00    34.00     34.00HENDERSON
2 762331          53.48    55.00     57.61BOYD
2 782341         162.83   177.00    203.47FAYETTE
2  62351         675.01   695.00    729.65JEFFERSON
2 7723I6          18.05    17.70     17.11MARSHALL
2 7723G1           8.00     8.00      8.00BALLARD
2 7723G2          57.98    56.50     54.10MCCRACKEN
2 7823L1          38.18    40.70     45.26MADISON
2 7523M1          14.50    14.50     14.50UNION
2  723R2          26.21    29.00     34.33BOONE
2 7823RA          13.89    14.50     15.57JESSAMINE
2 7823S6          22.71    24.00     26.30CLARK
2 7623S8          30.90    32.30     34.77GREENUP
2 7623SA          11.83    11.60     11.21LAWRENCE
2 7923T2           9.05     9.30      9.71BUTLER
2 7523T5          77.18    79.00     82.11DAVIESS
2 7523T8           5.73     5.80      5.90HANCOCK
2 7923TI          53.56    58.50     67.78WARREN
2 272411         266.23   296.00    353.43ANNE ARUNDEL
2 272412         570.63   603.00    661.14BALTIMORE
2 272413         920.98   915.00    905.10BALTIMORE (CITY)
2 272414          62.82    69.00     80.71CARROLL
2 272415          48.47    56.00     71.34HOWARD
2 152421         450.20   503.00    605.56MONTGOMERY
2 152422         545.46   612.00    742.04PRINCE GEORGES
215524G1          83.49    85.00     87.57ALLEGANY
215524G2          22.19    22.50     23.01GARRETT
2 2724I2         100.97   116.00    146.38HARFORD
223824J1          83.17    89.00     99.64FREDERICK
223824J2          98.74   103.00    110.51WASHINGTON
2 212511         555.95   565.00    580.40SUMMIT
2 212521         359.36   366.00    377.34STARK
2  72531         952.39   995.00   1070.32HAMILTON
2 212541        1741.93  1760.00   1790.52CUYAHOGA
2 212542         185.47   194.00    209.09LAKE
21962551         803.31   830.00    876.47FRANKLIN
2 212552          57.88    62.50     71.03GEAUGA
2 202561         115.89   122.00    132.89GREENE
2 202562          81.29    86.50     95.93MIAMI
2 202563         589.36   610.00    646.01MONTGOMERY
2  72571         218.94   225.00    235.45BUTLER
2 762581          57.50    57.50     57.50LAWRENCE
21952591         110.88   113.00    116.61ALLEN
2 2125A1         248.73   256.00    268.59LORAIN
2 2025B1         140.97   144.00    149.18CLARK
2 1925C1          98.00    98.00     98.00JEFFERSON
2 2525D1         479.76   487.00    499.30LUCAS
2 1925E1          79.91    79.05     77.62BELMONT
219325F1         307.36   302.00    293.25MAHONING
219325F2         226.55   232.00    241.36TRUMBULL
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(continued)

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220025I1          75.03      79.00      86.08ERIE
219625J1          68.48      70.00      72.59FAIRFIELD
219625J2         101.93     106.50     114.57LICKING
219625K2          39.39      40.00      41.02PICKAWAY
219925L1          64.79      66.00      68.06MARION
220025M1          35.64      33.70      30.69OTTAWA
2 2525M2          80.88      83.00      86.65WOOD
2 7625N2          82.59      82.00      81.01SCIOTO
2 212501         111.13     121.00     139.46PORTAGE
219725P1         129.88     132.00     135.59RICHLAND
219425Q1          55.79      57.00      59.07WASHINGTON
219725R1          41.11      41.30      41.60ASHLAND
219825R2          32.89      33.20      33.70COSHOCTON
219925R3          51.49      53.50      57.01CRAWFORD
219625R4          39.78      41.00      43.10DELAWARE
220025R6          50.85      52.00      53.97HURON
2 2125R8          75.59      76.50      78.03MEDINA
219925R9          20.94      22.10      24.18MORROW
220025RA          59.29      59.00      58.50SANDUSKY
220025RB          60.57      59.50      57.75SENECA
219925RD          22.21      22.40      22.70WYANDOT
219325S1          97.21      96.05      94.13ASHTABULA
2 2025T3          60.50      52.00      40.29DARKE
219525T4          59.63      62.50      67.58HANCOCK
219925T5          29.23      28.40      27.06HARDIN
219625T7          28.15      28.40      28.80MADISON
2 2025TA          34.89      35.50      36.52PREBLE
219925TD          23.63      23.70      23.80UNION
2 1925U2         107.28     105.50     102.58COLUMBIANA
219825U3          37.88      36.70      34.80GUERNSEY
219825U5          78.75      79.00      79.40TUSCARAWAS
2  725V3          93.39      94.00      95.01CLERMONT
2  725V5          79.34      83.00      89.47WARREN
219425W1          52.32      56.00      62.72ATHENS
2 7625W2          26.03      25.20      23.87GALLIA
219425W5          21.41      21.30      21.10MEIGS
2 1925W6          16.17      17.40      19.66MONROE
219825W8          80.50      80.50      80.50MUSKINGUM
219825WA          28.13      29.60      32.21PERRY
21052611         236.80     249.00     270.75LEIGH
21052612         205.71     213.00     225.71NORTHHAMPTON
21072621         138.79     137.00     134.06BLAIR
21932631         253.98     257.00     262.09ERIE
21092641         139.74     148.00     162.86CUMBERLAND
21092642         228.00     228.00     228.00DAUPHIN
21072651         191.52     185.00     174.61CABRIA
21072652          77.19      76.00      74.05SOMERSET
21122661         294.52     303.00     317.68LANCASTER
2 102671         357.09     386.00     439.58BUCKS
2 102672         249.08     277.00     330.86CHESTER
2 102673         592.92     605.00     625.68DELAWARE
2 102674         595.98     624.00     673.68MONTGOMERY
2 102675        2013.90    1990.00    1950.78PHILADELPHIA
2 112681        1623.99    1630.00    1640.06ALLEGHENY
2 112682         202.19     204.00     207.04BEAVER
2 112683         214.39     215.00     216.00WASHINGTON
2 112684         362.87     375.00     396.13WESTMORELAND
21102691         293.17     298.00     306.22BERKS
210826A1         224.59     227.00     231.07LACKAWANNA
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210826B1     337.35   344.00   355.36LUZERNE
211126C1     254.05   265.00   284.31YORK
211126G1      57.59    58.50    60.03ADAMS
210726G2      44.67    45.70    47.46BEDFORD
223826G3      97.16   100.50   106.31FRANKLIN
210626H1      56.89    56.60    56.10BRADFORD
211326H2     113.19   113.50   114.00LYCOMING
2 1126I1     118.44   123.00   130.98BUTLER
2 1126I2     106.79   108.00   110.03LAWRENCE
219326I3     127.79   126.00   123.06MERCER
219326J1      79.79    81.00    83.05CRAWFORD
210926L1      95.19    95.50    96.00LEBANON
211326N1     100.59   100.00    99.00NORTHUMBERLAND
2 1126R1      76.37    75.60    74.32ARMSTRONG
211326R6      39.07    38.60    37.81CLINTON
210626S2      33.09    34.00    35.56SUSQUEHANNA
210926T4      26.59    27.50    29.08PERRY
211326T5      29.79    30.70    32.27SNYDER
211326T6      29.63    29.40    29.00UNION
210826U2      52.94    55.20    59.16COLUMBIA
21442711      26.34    28.50    32.49AMHERST
21442712      40.67    42.50    45.72CAMPBELL
21442713      55.78    54.00    51.15LYNCHBURG (CITY)
21672721      29.03    31.50    36.08YORK
21672722     114.65   122.00   135.32HAMPTON (CITY)
21672723     134.00   142.00   155.00NEWPORT NEWS
21672733     313.00   300.00   279.49NORFOLK (CITY)
21672734     119.97   123.00   128.21PORTSMOUTH (CITY)
21672735      89.84    86.00    79.95CHESAPEAKE (CITY)
21672736     138.43   165.00   221.72VIRGINIA BEACH (CITY)
21432741     102.73   123.00   166.56CHESTERFIELD
21432742     145.19   155.00   172.85HENRICO
21432743     222.19   221.00   219.01RICHMOND (CITY)
21452751      19.87    24.00    32.98SALEM CITY (CITY)
21452751      70.37    64.00    54.59ROANOKE
21452752      99.89    99.00    97.52ROANOKE (CITY)
2 152761     174.98   178.00   183.14ARLINGTON
2 152762     388.05   445.00   559.86FAIRFAX
2 152763     106.00   116.00   130.00ALEXANDRIA CITY
2 152764      10.00    11.50    12.50FALLS CHURCH CITY
214727H1       5.93     6.00     6.10BEDFORD (CITY)
214727H1      30.59    28.20    24.61BEDFORD
214727H2      62.11    62.00    61.80PITTSYLVANIA
214727H3      48.00    48.00    48.00DANVILLE (CITY)
214827J1       7.95     7.90     7.80CLARKE
214827J3      22.41    22.30    22.10SHENANDOAH
214827J4      14.09    15.20    17.24WARREN
2 1527K3      34.60    38.00    44.44LOUDOUN
2 1527M2      80.49    99.00   140.40PRINCE WILLIAM
214527N1      38.54    42.00    48.47MONTGOMERY
214527N2      28.79    29.40    30.43PULASKI
214627N3      10.86    12.30    15.13RADFORD (CITY)
214327P1      26.18    30.00    37.68PRINCE GEORGE
2 9727Q1      41.12    39.70    37.43WASHINGTON
2 9727Q2      16.61    16.20    15.52BRISTOL (CITY)
214627R1      31.46    38.00    52.24ALBERMARLE
214627R2      40.98    42.20    44.29AUGUSTA
214627RF      37.92    41.00    46.70CHARLOTTESVILLE (CITY)
214827RA      16.01    16.20    16.50PAGE
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214627RC       44.36    46.50    50.28ROCKINGHAM
214627RH       14.34    15.20    16.74HARRISONBURG (CITY)
214627RI       23.96    25.00    26.82STAUNTON (CITY)
214627RJ       17.27    17.70    18.42WAYNESBORO (CITY)
214327S3       34.73    37.50    42.62HANOVER
2 9727T1       24.55    24.50    24.40SCOTT
214527T1       11.92    13.10    15.32ALLEGHANY
214727TA       28.05    28.30    28.70FRANKLIN
214527T4       17.21    17.40    17.70BOTETOURT
214727TD       47.45    50.20    55.14HENRY
2 9727TF       24.25    22.50    19.84LEE
2 9727TH       27.24    26.30    24.79RUSSELL
2 9727TJ       31.95    31.00    29.47SMYTH
2 9727TL       38.71    38.30    37.61WISE
214527TN        5.59     5.60     5.59CLIFTON FORGE (CITY)
214527TO       10.51    10.10     9.44COVINGTON (CITY)
214727TQ       20.39    21.00    22.05MARTINSVILLE (CITY)
2 9727TR        4.75     4.70     4.60NORTON  (CITY)
214727UB        7.07     6.90     6.61SOUTH BOSTON (CITY)
214727U6       32.83    32.90    33.00HALIFAX
216727V5       34.73    34.80    34.90NANSEMOND
214327VA       37.39    38.00    39.02PETERSBURG (CITY)
21562811      245.53   239.00   228.48KANAWHA
2 762821      107.69   108.00   108.50CABELL
2 762822       39.50    39.50    39.50WAYNE
2 192831       29.00    29.00    29.00BROOKE
2 192832       40.68    39.50    37.59HANCOCK
2 192841       37.19    37.50    38.00MARSHALL
2 192842       65.00    65.00    65.00OHIO
215728G2       73.18    75.00    78.12HARRISON
2 7628I1       24.33    23.80    22.93MASON
215728J1       56.30    62.50    74.43MONONGALIA
219428K2       82.09    83.00    84.52WOOD
215728R1       60.56    63.00    67.27MARION
219428R2        7.61     7.50     7.30PLEASANTS
219428R3       10.00    10.00    10.00TYLER
219428R4       19.75    19.70    19.60WETZEL
219428S1       20.49    21.90    24.47JACKSON
215628S2       25.05    26.40    28.80PUTNAM
223828U1       35.40    37.30    40.68BERKELEY
215528U2        8.45     8.70     9.11GRANT
214828U5       19.25    20.60    23.05JEFFERSON
215528U6       23.00    23.00    23.00MINERAL
215828V4       57.21    52.50    45.47MCDOWELL
215828V5       65.19    65.50    66.00MERCER
215828V7       68.39    67.50    66.03RALEIGH
215828V9       31.85    32.10    32.50WYOMING
2  13111      658.95   650.00   635.33JEFFERSON
2 413121       49.22    50.50    52.69RUSSELL
2 463131       94.59    94.00    93.01ETOWAH
2 473141      181.44   200.00   235.36MADISON
2 423151      338.60   325.00   303.51MOBILE
2 453161      179.79   178.00   175.04MONTGOMERY
2  13171      123.52   129.00   138.67TUSCALOOSA
2 4231G1       55.06    57.50    61.80BALDWIN
2 4631H1      100.35   104.00   110.36CALHOUN
2 4331I1       50.10    51.50    53.90COLBERT
2 4331I3       23.11    24.90    28.18FRANKLIN
2 4931J1       41.56    50.00    68.25DALE
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2 4831K1         57.88     59.70      62.85DALLAS
2 4431L1         38.49     38.80      39.30JACKSON
2 4731L3         52.29     58.00      68.95MARSHALL
2 4731L4         72.02     78.50      90.64MORGAN
2 4331M1         68.37     70.50      74.18LAUDERDALE
2 4731M2         40.36     42.50      46.31LIMESTONE
2  131R2         25.29     25.90      26.94BLOUNT
2 4131R3         36.61     39.50      44.84CHAMBERS
2  131RC         26.82     27.80      29.49ST. CLAIR
2  131RD         34.77     35.50      36.74SHELBY
2  131RF         56.97     58.00      59.75WALKER
2 4831S1         22.99     26.50      33.63AUTAUGA
2 4231S6         35.79     36.40      37.42ESCAMBIA
2 4531T6         33.28     34.50      36.62ELMORE
2 4931T9         58.48     60.00      62.60HOUSTON
2 4131TA         57.57     62.50      71.68LEE
2 323211        467.63    530.00     653.68BROWARD
22533221        520.00    520.00     520.00DUVAL
2 323231       1152.01   1178.00    1222.63DADE
22523241        317.00    331.00     355.72ORANGE
22523242         72.95     76.00      81.35SEMINOLE
2 423251        197.59    197.00     196.00ESCAMBIA
2 423252         34.50     34.50      34.50SANTA ROSA
22513261        451.76    470.00     502.05HILLSBOROUGH
22513262        446.67    460.00     483.10PINELLAS
2 323271        299.75    315.00     342.16PALM BEACH
2 4232G1         68.69     67.50      65.55BAY
2 4232G2          9.50      9.50       9.50GULF
225232H1        207.65    238.00     299.16BREVARD
225332I1         22.09     26.00      34.18CLAY
225432J3         25.74     98.08    2544.13LEON
225532K1         60.09     61.00      62.53MONROE
2 4232L1         74.72     86.00     108.86OKALOOSA
2 4232R1          7.95      7.90       7.80CALHOUN
2 4232R4         37.29     36.70      35.72JACKSON
2 4232R6         16.29     16.30      16.29WALTON
225832S1         94.99    103.00     117.89ALACHUA
225832SC         63.76     66.50      71.32MARION
225332SD         19.39     19.10      18.61NASSAU
225832SE         33.97     34.40      35.11PUTNAM
225332SF         33.11     33.30      33.60ST.JOHNS
225732T3         34.78     36.00      38.11INDIAN RIVER
225232T4         65.59     66.50      68.03LAKE
225232T5         21.77     21.60      21.30OSCEOLA
225132T7        228.80    246.00     277.63POLK
225232T9        156.81    171.00     197.61VOLUSIA
225532U2         27.61     34.00      48.30COLLIER
225532U8         80.41     87.50     100.76LEE
225632U9         82.38     84.50      88.15MANATEE
225732UC         49.37     51.50      55.25SAINT LUCIE
225632UD        102.38    111.00     127.04SARASOTA
22623311         92.59     92.00      91.01DOUGHERTY
2 333321         75.43     89.00     117.51CLAYTON
2 333322        166.33    194.00     251.20COBB
2 333323        354.30    403.00     500.07DEKALB
2 333324        630.98    625.00     615.15FULTON
2 333325         59.17     66.00      79.23GWINNETT
22593331        165.23    189.00     236.75RICHMOND
2   93341        50.79     52.00      54.08WALKER
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2 413351        15.48     18.00     23.16CHATTAHOOCHEE
2 413352       186.50    200.00    224.74MUSCOGEE
22613361       153.00    153.00    153.00BIBB
22613362        56.69     64.50     80.06HOUSTON
22603371       199.76    195.00    187.31CHATHAM
226733G2        51.00     51.00     51.00GLYNN
226433H1        54.94     60.00     69.51CLARKE
226333L1        41.81      8.30      4.81LOWNDES
226133M1        15.48     16.40     18.05PEACH
226533R1        32.20     34.10     37.51BARTOW
2   933R4       25.29     27.70     32.24CATOOSAA
2   933R8        9.41      9.60      9.90DADE
2 3333R9        24.51     25.30     26.67DOUGLAS
226533RC        71.07     73.50     77.73FLOYD
2 3333RI        20.88     24.80     33.12HENRY
226533RM        29.43     30.10     31.24POLK
225933S3        17.97     23.00     34.95COLUMBIA
226633S8        55.82     59.50     66.17HALL
226133T1         5.93      6.00      6.10CRAWFORD
2 4133T4        11.75     12.30     13.27HARRIS
226133T9        11.01     11.50     12.36MONROE
2 4133TD         6.87      6.70      6.41STEWART
2 4133TH        46.59     47.50     49.04TROUP
226133UF        10.13     12.10     16.29JONES
226133UN         8.17      8.60      9.36TWIGGS
2 853411       217.10    225.00    238.80HINDS
2 4234G1        18.35     22.70     32.50HANCOCK
2 4234G2       141.93    153.00    173.42HARRISON
2 4234G3        73.01     83.00    102.89JACKSON
2 8534J1        39.09     40.00     41.55RANKIN
2 8634K1        78.66     76.00     71.75WASHINGTON
2 4334R1        27.22     26.10     24.32ALCORN
2 8634R3        57.19     56.00     54.05BOLIVAR
2   334R7       32.27     36.00     43.21DESOTO
2 8634RH        47.31     42.30     35.05SUNFLOWER
2 4334RL        15.71     16.20     17.04TISHOMINGO
2 8734S9        75.57     78.00     82.21LAUDERDALE
2 8534SC        33.69     34.00     34.50MADISON
223334SK        43.39     44.00     45.02WARREN
2 8934T1        38.74     37.50     35.51ADAMS
2 8834T7        59.87     62.00     65.71FORREST
2 8834TE        59.69     58.50     56.56JONES
2 4234TJ         0.00     27.00     27.00PEARL RIVER
21683511       140.50    150.00    167.30BUNCOMBE
21143521       323.65    352.00    404.99MECKLENBURG
21703531       126.52    132.00    141.66DURHAM
21693541       281.34    288.00    299.43GUILFORD
21703551       201.11    226.00    274.74WAKE
21693561       214.16    219.00    227.30FORSYTH
216935G1        93.77     96.50    101.22ALAMANCE
217235H1        22.15     23.50     25.92BRUNSWICK
211435I1        73.34     77.00     83.51CABARRUS
217135L1       194.68    238.00    334.05CUMBERLAND
211435M1       139.29    146.00    157.90GASTON
214735N1        73.85     74.70     76.12ROCKINGHAM
21733501        90.57     93.00     97.19WAYNE
216935S5        91.62     99.00    112.67DAVIDSON
216935S6        18.04     18.90     20.41DAVIE
211435SI        48.94     52.00     57.53UNION
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216935SB      71.53     80.50      98.09RANDOLPH
216935SK      24.01     24.50      25.32YADKIN
217035T3      28.39     29.00      30.03CHATHAM
217335T9      64.23     63.70      62.81JOHNSTON
217335TB      63.50     63.50      63.50NASH
217235TC      78.53     82.50      89.55NEW HANOVER
217035TD      53.38     58.00      66.62ORANGE
217335TK      60.48     59.00      56.60WILSON
216735U3       5.69      5.40       4.94CAMDEN
216735U4       6.93      7.00       7.10CURRITUCK
217335U6      55.78     54.00      51.15EDGECOMBE
217335U8      16.82     16.00      14.71GREENE
217335UD      58.56     57.20      54.98LENOIR
216735UG      27.03     27.70      28.84PASQUOTANK
217335UI      76.46     79.50      84.83PITT
22593611      91.18     93.00      96.10AIKEN
21153621     253.28    278.00     324.81CHARLESTON
21163631      69.83     76.00      87.53LEXINGTON
21163632     233.31    248.00     274.59RICHLAND
21173641     225.72    233.00     245.65GREENVILLE
226036H1      51.59     52.50      54.04BEAUFORT
226036H2      11.83     11.30      10.46JASPER
211536I1      46.46     54.00      69.50BERKELEY
211836L1      21.88     21.00      19.59LEE
211836L2      81.03     80.50      79.60SUMTER
211736M1     168.22    178.00     195.59SPARTANBURG
211736R2     103.58    106.00     110.15ANDERSON
211736RC      50.94     54.00      59.51PICKENS
211436RF      85.53     89.00      95.09YORK
211836SA      40.91     39.20      36.49WILLIAMSBURG
211836S2      30.45     30.70      31.10CLARENDON
211836S3      56.29     57.50      59.57DARLINGTON
211836S4      32.62     33.90      36.13DILLON
211836S5      93.06    100.00     112.75FLORENCE
211436S7      42.45     44.40      47.85LANCASTER
211836S8      32.87     32.40      31.61MARION
211836S9      28.91     29.40      30.22MARLBORO
211536T4      27.60     30.90      37.31DORCHESTER
2   93711    254.38    258.00     264.14HAMILTON
2  993721     63.07     61.00      57.69ANDERSON
2  993722     60.26     63.00      67.84BLOUNT
2  993723    267.17    272.00     280.24KNOX
2   33731    712.66    740.00     787.92SHELBY
2  983741    446.76    465.00     497.07DAVIDSON
210037G1      23.98     25.70      28.84CARROLL
210037G2      47.15     51.60      59.98GIBSON
2 9737H1      42.27     43.30      45.06CARTER
2 9737H4      68.07     70.50      74.74WASHINGTON
2 9737J1      32.11     33.70      36.51HAWKINS
2 9737J2     124.90    131.00     141.83SULLIVAN
2 9837K1      60.07     65.00      74.13RUTHERFORD
210037R3      14.43     14.80      15.42CROCKETT
2 6137R5      29.48     30.70      32.84DYER
2 4337R8      18.57     19.80      22.02HARDIN
210037R9      23.19     23.20      23.19HAYWOOD
2 6137RD      22.11     23.40      25.70LAUDERDALE
210037RF      62.99     65.30      69.33MADISON
2 6137RH      29.45     30.30      31.76TIPTON
2 9837S2      10.70     12.40      15.85CHEATHAM        (continued)
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2 9837SG        28.93     30.90     34.47ROBERTSON
2 9837SI        44.42     57.00     87.05SUMNER
2 9837SK        27.86     30.90     36.73WILLIAMSON
2 9837SL        31.99     38.00     50.74WILSON
2 4437TI         6.33      6.70      7.35SEQUATCHIE
2 4437TC        21.53     21.60     21.70MARION
2 9737U5        45.77     49.40     56.10GREENE
2 9737U7         7.67      7.80      8.00HANCOCK
2 9937U9        24.41     24.60     24.90LOUDON
2 9937UE        41.02     39.60     37.33ROANE
22764111       150.20    160.00    177.79CHAMPAIGN
2 344121      5451.08   5575.00   5787.83COOK
2 344122       406.28    449.00    530.70DUPAGE
2 344123       242.82    260.00    291.41KANE
2 344124       344.07    363.00    396.91LAKE
2 344125        99.50    105.00    114.84MCHENRY
2 344126       227.80    245.00    276.64WILL
22124131       162.69    170.00    182.91ROCK ISLAND
22784141       125.89    126.50    127.50MACON
22744151       198.63    205.00    216.06PEORIA
22744152       112.74    117.00    124.44TAZEWELL
22734161       241.45    258.00    288.19WINNEBAGO
2 354171       245.98    249.00    254.10MADISON
2 354172       276.38    280.00    286.13ST.CLAIR
22774181       158.15    163.00    171.41SANGAMON
228341H1       113.00    113.00    113.00LASALLE
227341R1        23.52     26.00     30.73BOONE
228341R2        37.29     38.20     39.75BUREAU
227341R3        63.18     70.00     83.09DEKALB
228341R4        24.70     26.30     29.19GRUNDY
221241R6        51.17     53.00     56.19HENRY
228141R7        33.65     34.20     35.12IROQUOIS
221341R8        21.61     21.80     22.10JO DAVIS
228141R9       100.27    103.00    107.70KANKAKEE
2 3441RA        23.03     27.00     35.26KENDALL
227941RB        63.09     62.50     61.51KNOX
228141RC        41.03     41.10     41.20LIVINGSTON
227441RD        12.90     12.90     12.90MARSHALL
227341RF        41.36     43.50     47.30OGLE
228341RG         4.61      5.30      6.69PUTNAM
227341RI        48.68     51.00     55.10STEPHENSON
227441RL        25.89     26.50     27.53WOODFORD
228041S1        70.09     71.00     72.53ADAMS
228441SA        19.82     19.00     17.69DOUGLAS
228441S7        45.06     48.00     53.33COLES
228141SC        16.61     16.80     17.10FORD
227941SD        40.73     41.70     43.36FULTON
221441SF        23.95     24.80     26.28HANCOCK
227741SH        35.37     36.40     38.19LOGAN
227541SJ        94.50    100.00    109.89MCLEAN
227741SM         9.18      9.80     10.91MENARD
227641SV        98.78     97.00     94.08VERMILLION
2 7741T1        14.07     14.20     14.40ALEXANDER
228241T9        34.97     36.50     39.18FRANKLIN
228241TD        50.16     56.00     67.32JACKSON
2 7741TJ        14.11     13.70     13.03MASSAC
2 3541TK        17.16     19.60     24.48MONROE
2 7741TM         3.43      3.50      3.60POPE
2 7741TN         9.21      9.70     10.57PULASKI
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228241TQ        24.07     27.00     32.70SALINE
228241TW        46.24     49.00     53.95WILLIAMSON
2 754211       168.93    175.00    185.60VANDERBURG
22074221       260.43    272.00    292.43ALLEN
2 344231       540.00    540.00    540.00LAKE
2 344232        75.99     85.00    102.53PORTER
2 234241       773.98    780.00    790.12MARION
2  64251        68.48     70.00     72.59CLARK
2  64252        54.09     55.00     56.54FLOYD
22054261       120.52    126.00    135.69DELAWARE
22044271       246.39    247.00    248.00ST. JOSEPH
22064281       107.05    111.00    117.90VIRGO
220842G1        17.79     18.40     19.45CARROLL
220942G2        41.17     41.00     40.70CASS
220442G4        33.59     34.50     36.06MARSHALL
2 7542H3        17.92     18.90     20.64PERRY
220442I1       117.28    124.00    136.07ELKHART
220442I2        45.17     47.00     50.20KOSCIUSKO
221042J2        37.38     38.60     40.70LAWRENCE
2 2342L1        50.87     53.00     56.74JOHNSON
220442M1       103.74    108.00    115.48LAPORTE
220542N1       133.25    137.50    144.87MADISON
22094201        40.34     41.50     43.49MIAMI
220642P1        16.01     15.60     14.92VERMILLION
220942R4        31.15     30.80     30.21CLINTON
220942R6        80.09     81.00     82.52GRANT
220942R7        80.57     83.00     87.20HOWARD
220942R8        34.71     34.60     34.40HUNTINGTON
220942RI        16.70     17.50     18.90TIPTON
220842RH       103.26    110.00    122.23TIPPECANOE
220942RJ        34.99     35.30     35.80WABASH
2 2342S1        29.22     30.50     32.75BOONE
220642S2        23.89     24.20     24.71CLAY
221142S3        24.66     25.70     27.52FAYETTE
2 2342S5        45.99     50.00     57.48HAMILTON
2 2342S6        32.04     34.50     39.03HANCOCK
2 2342S7        48.05     53.00     62.44HENDRICKS
221142S8        50.68     53.00     57.09HENRY
2 2342SA        39.55     42.00     46.42MORGAN
221142SE        28.97     30.50     33.22RANDOLPH
2 2342SG        36.47     38.00     40.67SHELBY
221142SI        79.59     80.50     82.02WAYNE
2  742T4        29.79     29.50     29.00DEARBORN
221042TD        74.30     83.00     99.88MONROE
2 7542T6        29.28     30.50     32.64DUBOIS
2 7542T8        29.67     29.80     30.00GIBSON
221042T9        26.33     26.70     27.31GREENE
2  742TE         3.89      3.90      3.89OHIO
2 7542TF        12.50     12.50     12.50PIKE
2 7542TG        19.90     21.50     24.46POSEY
2 7542TI        16.39     16.70     17.21SPENCER
220642TJ        20.87     20.70     20.40SULLIVAN
2 7542TL        24.84     27.00     31.02WARRICK
22294311       209.51    228.00    262.59WASHTENAW
22274321       110.13    115.00    123.60BAY
2 264331       554.78    620.00    746.75MACOMB
2 264332       819.16    890.00   1022.26OAKLAND
2 264333      2696.95   2715.00   2745.33WAYNE
22284341       421.42    444.00    484.38GENESEE
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22254351      400.81     416.00     442.60KENT
22294361      140.79     142.00     144.02JACKSON
22304371      192.24     202.00     219.39KALAMAZOO
22264381       43.43      46.50      52.10CLINTON
223043H1      139.88     142.00     145.59CALHOUN
22264382       57.62      63.50      74.69EATON
22264383      244.69     265.00     302.74INGHAM
22254391      158.00     158.00     158.00MUSKEGON
222743A1      212.10     220.00     233.82SAGINAW
220443G2       37.23      37.00      36.60CASS
223143I1       35.45      32.60      28.33CHIPPEWA
222843J2       46.99      51.00      58.46LAPEER
2 2643J3      113.32     118.50     127.66ST CLAIR
2 2543M2      113.49     115.00     117.55MONROE
215943R3       34.09      33.50      32.52DELTA
215943R4       24.30      24.30      24.30DICKINSON
215943R9       23.52      22.70      21.39MENOMINEE
223043T3       30.08      31.80      34.87BARRY
220443T4      166.23     172.00     182.05BERRIEN
222743TC       58.13      61.50      67.54MIDLAND
222543TF      114.27     121.00     133.10OTTAWA
222843TG       58.13      61.50      67.54SHIAWASSEE
220443TH       53.98      57.10      62.70VANBUREN
2 804411      223.16     228.00     236.29ST LOUIS
21744421       44.17      46.00      49.21CLAY
2  84431      129.54     140.00     159.37ANOKA
2  84432      109.08     127.00     163.93DAKOTA
2  84433      912.94     925.00     945.44HENNEPIN
2  84434      444.76     452.00     464.32RAMSEY
2  84435       70.20      77.00      89.85WASHINGTON
2 8044R4       28.10      27.10      25.49CARLTON
2 8044R7        3.65       3.90       4.34COOK
2 8044RD       13.41      11.70       9.30LAKE
217744RK       36.65      35.00      32.40POLK
2 8244S1       18.57      19.00      19.72BENTON
2  844S3       24.85      26.20      28.60CRAVER
2 8244SA       30.19      29.60      28.63KANDIYOHI
2 8244SF       27.55      26.90      25.84MORRISON
2 8044SG       17.23      16.70      15.84PINE
2 8444SI       23.34      22.40      20.90RENVILLE
2 8244SJ       14.91      15.10      15.40SHERBURNE
2 8244SK       89.55      94.50     103.36STEARNS
2 8244SN       23.24      22.30      20.80TODD
2 8244SP       33.79      34.40      35.42WRIGHT
2 8444T1       50.56      55.00      63.29BLUE EARTH
2 8444T2       28.71      28.60      28.40BROWN
2 8344T5       22.75      21.40      19.32FARIBAULT
2 8344T6       22.27      20.70      18.30FILLMORE
2 8344T7       38.79      38.50      38.00FREEBORN
2 8344T8       33.43      33.20      32.80GOODHUE
2 8144T9       16.93      16.70      16.30HOUSTON
2 8344TE       25.84      24.20      21.69MARTIN
2 8344TF       46.64      44.00      39.91MOWER
2 8444TH       23.07      23.20      23.40NICOLLET
2 8344TJ       75.72      80.00      87.67OLMSTED
2 8444TL       20.91      20.50      19.82REDWOOD
211944TN       11.49      11.20      10.72ROCK
2  844TO       26.89      28.30      30.80SCOTT
2 8344TQ       26.59      26.30      25.80STEELE
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2 8144TR              16.85      15.80      14.18WABASHA
2 8144TU              42.71      43.80      45.67WINONA
2 804511              43.68      42.50      40.58DOUGLAS
21614521             141.53     147.00     156.58BROWN
2 174531             111.56     108.00     102.31KENOSHA
21604541             268.58     292.00     335.75DANE
2 174551            1083.39    1078.00    1069.08MILWAUKEE
2 174552             201.12     219.00     252.47WAUKESHA
2 174561             163.37     167.00     173.22RACINE
216145G1              79.18      81.00      84.11FOND DU LAC
216245G2              89.99      91.50      94.07SHEBOYGAN
2 1745I1              47.12      50.50      56.67OZAUKEE
2 1745I2              54.56      59.50      68.75WASHINGTON
216045J1              35.29      35.00      34.50SAUK
2 1745K1              61.33      65.00      71.61WALWORTH
2 8045R3              11.09      11.10      11.09BAYFIELD
2 8045R4               8.45       8.40       8.30BURNETT
216345R5              45.23      44.70      43.81CHIPPEWA
216345R6              29.47      28.00      25.70CLARK
216245R7              20.00      19.00      17.43DOOR
216345R8              25.32      26.30      28.00DUNN
216345R9              60.87      63.00      66.70EAU CLAIRE
215945RA               3.17       3.00       2.72FLORENCE
216445RF              92.18      94.00      97.09MARATHON
215945RG              33.50      33.50      33.50MARINETTE
215945RH              23.99      23.70      23.21OCONTO
216445RP              30.60      29.60      27.99SHAWANO
2 8145S2              13.43      12.90      12.05BUFFALO
216145S3              24.43      25.90      28.54CALUMET
216245S7              18.05      17.70      17.11KEWAUNEE
2 8145S8              76.07      78.50      82.71LA CROSSE
216145SH             118.52     124.00     133.70WINNEBAGO
216245S9              78.59      79.50      81.02MANITOWOC
216145SB             112.86     116.50     122.82OUTAGAMIE
216445SD              39.41      41.00      43.77PORTAGE
2 8145SE              22.53      22.30      21.90TREMPEALEAU
216445SF              34.43      33.90      33.02WAUPACA
216445SI              63.39      64.00      65.01WOOD
216045T1              36.85      36.50      35.90COLUMBIA
221345T4              46.47      47.50      49.26GRANT
227345TA             127.97     131.00     136.19ROCK
2 8145TB              23.50      22.10      19.93VERNON
2 555111              81.78      80.00      77.10SEBASTIAN
2 575121             278.51     287.00     301.72PULASKI
2 565131              34.09      37.50      43.95MILLER
2 6051G1              49.36      52.30      57.58GARLAND
2 5651H2              10.47      10.30      10.00LAFAYETTE
2 5651H3              10.09      11.60      14.63LITTLE RIVER
2 5851J1              89.00      89.00      89.00JEFFERSON
2 6151K1              74.57      72.50      69.16MISSISSIPPI
228551R2              43.96      48.10      55.89BENTON
2 5551R6              24.65      26.50      29.88CRAWFORD
2 5751R7              30.62      35.00      43.78FAUIKNER
228551RJ              68.19      75.00      87.91WASHINGTON
2 6151S3              51.37      53.50       0.00CRAIGHEAD
2   351S4             50.39      51.00      52.02CRITTENDEN
2 6151SC              30.97      29.50      27.19POINSETT
2 5951T8              26.85      27.40      28.33COLUMBIA
2 5751TF              25.59      27.50      30.99LONOKE
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(continued)

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|---|---|---|---|
| 2 6051TK | 31.90 | 33.00 | 34.90SALINE |
| 2 5951TL | 49.79 | 51.00 | 53.08UNION |
| 22325211 | 273.48 | 295.00 | 334.76EAST BATON ROUGE |
| 22325221 | 154.81 | 146.00 | 132.38CALCASIEU |
| 22335231 | 115.75 | 120.00 | 127.43OUACHITA |
| 22325241 | 291.33 | 330.00 | 406.60JEFFERSON |
| 22325242 | 650.00 | 660.00 | 675.00ORLEANS |
| 22325243 | 43.74 | 50.00 | 62.54ST. BERNARD |
| 2 565251 | 65.39 | 66.00 | 67.01BOSSIER |
| 2 565252 | 236.94 | 231.00 | 221.41CADDO |
| 2 5952G4 | 41.66 | 43.00 | 45.31WEBSTER |
| 223252H1 | 13.60 | 14.90 | 17.34GRANT |
| 223252I1 | 26.33 | 27.00 | 28.14PLAQUEMINES |
| 223252J1 | 119.27 | 122.00 | 126.67RAPIDES |
| 223252K1 | 29.15 | 57.00 | 198.47VERNON |
| 223252R1 | 39.13 | 42.40 | 48.46AVOYELLES |
| 2 5952R4 | 16.71 | 17.20 | 18.03CLAIBORNE |
| 2 8952R5 | 23.45 | 24.00 | 24.93CONCORDIA |
| 223352R6 | 13.76 | 14.50 | 15.80EAST CARROLL |
| 223352R8 | 16.36 | 17.10 | 18.39JACKSON |
| 223352RB | 16.26 | 17.00 | 18.29MADISON |
| 223352RC | 33.89 | 34.50 | 35.52MOREHOUSE |
| 223352RE | 23.10 | 24.70 | 27.60RICHLAND |
| 223352RI | 13.69 | 15.70 | 19.73WEST CARROLL |
| 223252S1 | 51.79 | 53.80 | 57.31ACADIA |
| 223252S2 | 20.43 | 21.10 | 22.26ALLEN |
| 223252S3 | 21.43 | 24.30 | 29.99BEAUREGARD |
| 223252S4 | 7.27 | 7.40 | 7.60CAMERON |
| 223252S5 | 32.10 | 33.50 | 35.97EVANGELINE |
| 223252S6 | 57.56 | 60.00 | 64.28IBERIA |
| 223252S7 | 31.33 | 31.40 | 31.50IBERVILLE |
| 223252S8 | 30.06 | 29.00 | 27.30JEFFERSON DAVIS |
| 223252S9 | 98.37 | 107.00 | 123.13LAFAYETTE |
| 223252SA | 23.38 | 24.60 | 26.77POINTE COUPEE |
| 223252SB | 82.92 | 87.50 | 95.70ST. LANDRY |
| 223252SC | 31.41 | 33.50 | 37.28ST. MARTIN |
| 223252SD | 55.93 | 61.50 | 72.06ST. MARY |
| 223252SE | 40.55 | 43.00 | 47.41VERMILION |
| 223252SF | 16.27 | 16.40 | 16.60WEST BATON ROUGE |
| 223252T1 | 32.06 | 35.60 | 42.40ASCENSION |
| 223252T2 | 19.34 | 21.20 | 24.70ASSUMPTION |
| 223252T3 | 19.90 | 18.90 | 17.33EAST FELICIANA |
| 223252T4 | 60.26 | 63.00 | 67.84LAFOURCHE |
| 223252T5 | 32.21 | 36.00 | 43.36LIVINGSTON |
| 223252T6 | 25.96 | 28.50 | 33.29ST. CHARLES |
| 223252T7 | 9.68 | 10.30 | 11.40ST. HELENA |
| 223252T8 | 20.11 | 20.60 | 21.43ST. JAMES |
| 223252T9 | 20.85 | 22.20 | 24.64ST. JOHN THE BAPTIST |
| 223252TA | 52.88 | 65.00 | 92.10ST. TAMMANY |
| 223252TB | 67.24 | 75.00 | 90.03TANGIPAHOA |
| 223252TC | 70.82 | 80.50 | 99.76TERREBONNE |
| 223252TD | 46.00 | 46.00 | 46.00WASHINGTON |
| 223252TE | 12.37 | 11.50 | 10.17WEST FELICIANA |
| 21805311 | 319.08 | 330.00 | 349.04BERNALILLO (PART/WHOLE) |
| 218253G1 | 59.03 | 47.00 | 31.82CHAVES |
| 218453H1 | 36.89 | 36.00 | 34.55CURRY |
| 218253J1 | 50.35 | 46.00 | 39.53EDDY |
| 213953K2 | 16.39 | 18.00 | 21.04SANDOVAL |
| 218053K2 | 16.39 | 18.00 | 21.04SANDOVAL (PART/WHOLE) |

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213953L1        42.39     43.00     44.02MCKINLEY
218353M1        32.54     35.00     39.52OTERO
213953R6        24.80     23.80     22.21RIO ARRIBA
213953R7        50.57     46.50     40.40SAN JUAN
218153R9        50.00     51.00      1.50SANTA FE
218053RD        39.18     37.30     34.35VALENCIA (PART/WHOLE)
217953S3        19.11     19.30     19.60GRANT
217953S4         5.00      5.00      5.00HIDAIGO
218253S5        54.65     52.00     47.85LEA
218053SA        10.87     11.00     11.20SOCORRO (PART/WHOLE)
22025411       111.95    125.00    150.30COMANCHE
2 225421        30.54     33.00     37.55CANADIAN
2 225422        70.69     82.00    105.17CLEVELAND
2 225423       515.18    520.00    528.12OKLAHOMA
22015431        42.55     45.00     49.39CREEK
22015432        31.18     30.00     28.12OSAGE
22015433       376.72    395.00    427.48TULSA
220354H1        54.75     57.50     62.38GARFIELD
2 5554J1        61.00     61.00     61.00MUSKOGEE
2 5554K1        36.09     37.00     38.56PITTSBURG
2 2254RA        12.59     12.30     11.81KINGFISHER
2 2254RB        18.21     17.10     15.38LOGAN
228554S1        13.91     13.80     13.60ADAIR
228554S2        19.89     20.50     21.55CHEROKEE
228554S3        16.75     16.40     15.82CRAIG
228554S4        13.80     13.80     13.80DELAWARE
2 2254S6        20.34     19.40     17.92LINCOLN
228554S7        21.80     20.80     19.22MAYES
228554S9        10.03     10.10     10.20NEWATA
228554SA        30.20     28.90     26.85OTTAWA
228554SD        23.07     23.80     25.06ROGERS
2 5554SE        20.08     21.00     22.61SEQUOYAH
228554SF        16.61     15.00     12.63WAGONER
228554SG        42.65     43.50     44.94WASHINGTON
2 2254T5        29.89     29.30     28.33GRADY
2 2254T8        13.33     13.10     12.71MCCLAIN
2 5554U5         9.61      9.20      8.54HASKELL
2 5554U8         8.09      7.80      7.32LATIMER
2 5554U9        32.50     32.50     32.50LEFLORE
2 5554UB        13.00     12.30     11.20MCINTOSH
2 5554UE        36.89     35.30     32.79OKMULGEE
2 2254UG        41.39     42.00     43.02POTTAWATOMIE
21255511        20.17     19.00     17.18JONES
21255512       106.29     97.00     83.23TAYLOR
21225521       120.00     90.00     88.00POTTER
21225522        53.00     53.00     55.00RANDALL
21305531       260.34    280.00    316.17TRAVIS
22325542        68.39     69.00     70.01ORANGE
21325551       148.00    148.00    148.00CAMERON
21335561       239.42    251.00    271.55NUECES
2 135571        53.55     65.00     90.10COLLIN
2 135572      1238.54   1315.00   1453.23DALLAS
2 135573        67.83     74.00     85.58DENTON
2 135574        46.00     46.00     46.00ELLIS
21785581       356.02    370.00    394.53EL PASO
2 135591        42.17     44.00     47.22JOHNSON
2 135592       615.81    665.00    756.05TARRANT
2 1255A1       161.34    173.00    194.36GALVESTON
2 1255B1      1560.78   1690.00   1930.12HARRIS
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213155C1          72.47     78.00     88.19WEBB
213455D1         190.86    200.00    216.22LUBBOCK
212455E1          67.78     66.00     63.12MIDLAND
212455F1          86.69     87.00     87.50ECTOR
212655G1          72.26     75.00     79.78TOM GREEN
2 1455H1         806.56    840.00    898.87BEXAR
2 5655I1          66.33     70.00     76.56BOWIE
217855I1          70.14     73.50     79.44DONA ANA
212755J1          96.18     98.00    101.09SMITH
212955K1         151.91    146.00    136.63MCLENNAN
212355L1           6.50      6.50      6.50ARCHER
212355L2         133.17    121.00    103.06WICHITA
213755P2          42.56     40.50     37.27HOWARD
213255Q1         186.19    188.00    191.04HIDALGO
213355Q3          30.83     31.80     33.49KLEBERG
2 1355TD          26.28     27.50     29.65PARKER
2 1355TI          18.87     19.60     20.87WISE
2 5655U2          24.71     24.30     23.61CASS
212855U6          78.34     82.00     88.47GRAYSON
2 5655U7          76.18     78.00     81.12GREGG
2 5655U8          43.00     43.00     43.00HARRISON
2 1355UC          31.28     32.50     34.63KAUFMAN
2 5655UE           7.50      7.50      7.50MARION
2 1355UK           6.25      6.50      6.92ROCKWALL
213855UL          35.00     35.00     35.00RUSK
213855X2          44.24     47.00     51.98ANGELINA
213855X3          33.51     34.00     34.81CHEROKEE
223255X6          29.58     31.30     34.37HARDIN
223255X9          24.93     26.90     30.53JASPER
213855XE          31.00     34.80     42.21NACGODOCHES
223255XF          10.71     11.20     12.06NEWTON
213355Y1           8.74      9.30     10.29ARKANSAS
2 1455Y6          22.41     23.70     26.00COMAL
2 1455YD          32.91     36.00     41.81GAUDALUPE
213355YG          33.80     32.80     31.18JIM WELLS
213155YM          18.25     20.30     24.25MAVERICK
213355YP          47.22     52.50     62.66SAN PATRICIO
213555YS          53.29     54.50     56.57VICTORIA
2 1255Z3          97.00    105.00    119.85BRAZORIA
213655Z4          49.81     54.00     61.79BRAZOS
2 1255Z6          11.79     11.80     11.79CHAMBERS
2 1255Z9          49.31     53.00     59.77FORT BEND
2 1255ZE          33.71     34.50     35.85LIBERTY
2 1255ZG          33.78     37.50     44.66MONTGOMERY
2 1255ZI          25.84     28.00     32.00WALKER
22416111         189.17    218.00    276.56EL PASO
2 306121         163.19    165.00    168.05ADAMS (PART/WHOLE)
2 306122         144.74    140.00    132.43ARAPAHOE (PART/WHOLE)
2 306123         105.04    122.00    156.84BOULDER
2 306124         489.00    495.00    502.00DENVER
2 306125         202.75    220.00    252.13JEFFERSON
22426131         124.44    120.00    112.93PUEBLO
224461I2          54.11     54.30     54.60MESA
224361R5          70.64     80.00     98.52LARIMER
224661R6          19.34     18.00     15.95LOGAN
224361RE          81.38     83.50     87.15WELD
224561S1          10.83     11.70     13.29ALAMOSA
213961S2           2.71      2.90      3.23ARCHULETA
213961S7           1.93      1.60      1.15DOLORES
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213961SC            18.70      16.80      14.03LA PLATA
213961SE            13.45      13.10      12.52MONTEZUMA
22176211           157.52     167.00     184.09LINN
22126221           135.62     144.50     160.63SCOTT
22156231           286.77     291.00     298.17POLK
22136241            86.27      89.00      93.74DUBUQUE
2 366251            84.96      82.00      77.28POTTAWATAMIE
22896261           106.14     102.00      95.44WOODBURY
22166271           133.14     138.00     146.49BLACK HAWK
221462G1            45.39      45.70      46.20DES MOINES
221862R7            19.73      19.80      19.90HAMILTON
221862R9            12.77      12.60      12.30HUMBOLDT
221862RK            49.09      50.00      51.54WEBSTER
221862RM            17.53      15.80      13.27WRIGHT
221662S2            21.37      20.60      19.37BREMER
221662S3            21.97      22.10      22.30BUCHANAN
221662S4            17.17      17.30      17.50BUTLER
222062S5            50.47      50.00      49.21CERRO GORDIO
221662S9            27.36      26.30      24.61FAYETTE
222062SA            21.15      21.40      21.80FLOYD
221662SC            13.79      13.50      13.01GRUNDY
221862T4            26.57      25.10      22.82BOONE
2 3662TG            12.05      11.70      11.12MILLS
221562TM            57.66      64.50      77.79STORY
221262U4            56.29      56.00      55.50CLINTON
221362U8            20.41      18.90      16.61JACKSON
221762UB            65.23      73.00      88.12JOHNSON
221462UE            43.60      42.30      40.20LEE
221962UH            22.83      22.60      22.20MAHASKA
221262UL            34.87      35.60      36.84MUSCATINE
221962UP            44.06      42.00      38.76WAPELLO
2 246311           203.52     217.00     241.50JOHNSON
2 246312           190.76     195.00     202.26WYANDOTTE
22226321           154.76     159.00     166.32SHAWNEE
22216331           352.35     375.00     416.08SEDGWICK
22226357            52.69      57.00      64.99DOUGLAS
222363I1            62.50      65.00      69.37RENO
2 2463H1            53.51      57.00      63.33LEVENWORTH
222463J1            54.81      48.50      39.50SALINE
222263SB            11.60      12.40      13.85JEFFERSON
222163U4            38.78      40.00      42.10BUTLER
228563U7            22.59      23.20      24.24CHEROKEE
228563UA            38.28      40.80      45.36CRAWFORD
222163UE            26.50      27.60      29.52HARVEY
228563UG            26.11      26.30      26.60LABETTE
228563UL            42.41      40.00      36.27MONTGOMERY
2 246411           109.27     116.00     128.16CLAY
22856411            10.39      10.70      11.22MCDONALD
2 246412           569.84     688.00     719.37JACKSON
22856412            32.14      34.60      39.12NEWTON
2 246421            87.19      86.00      84.04BUCHANAN
2 356431            86.70      96.00     113.81JEFFERSON
2 356432            75.73      87.00     109.79ST CHARLES
2 356433           866.10     940.00    1077.76ST LOUIS
2 356434           691.00     655.00     610.00ST. LOUIS CITY
22866441           143.30     150.00     161.87GREENE
228764G1            43.59      44.50      46.05COLE
2 2464J1            28.16      30.00      33.33PLATTE
2 2464RM            15.91      15.80      15.60RAY
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228764S2         26.35     25.70     24.64AUDRAIN
228764S3         67.30     77.00     96.48BOONE
228764S4         24.64     25.80     27.85CALLAWAY
221464S5          7.94      7.30      6.34CLARKE
228064SC         38.09     39.00     40.56MARION
228764SH         21.25     20.90     20.31RANDOLPH
228564T2          9.24      8.10      6.48BARTON
2 2464T6         37.97     42.00     49.70CASS
228564TE         79.09     80.00     81.52JASPER
228664TG         24.04     25.70     28.71LAWRENCE
228864U3         46.93     50.00     55.56CAPE GIRARDEAU
2 6164U7         31.48     26.90     20.63DUNKLIN
228864UD         25.45     23.30     20.10NEW MADRID
2 6164UF         31.31     27.70     22.54PEMISCOT
228864UM         33.47     35.00     37.69SCOTT
228864U0         25.63     24.40     22.46STODDARD
22906511        174.98    172.00    167.14LANCASTER
2 366521        386.32    396.00    412.67DOUGLAS
2 366522         52.82     60.00     74.27SARPY
229165G1         29.83     29.00     27.66ADAMS
229165J1         39.57     40.00     40.71HALL
229165S4         28.04     29.70     32.67BUFFALO
228965T7         13.00     13.00     13.00DAKOTA
2 3665T9         35.55     34.90     33.83DODGE
2 3665TH         12.53     12.00     11.16WASHINGTON
2 3665U2         17.85     16.80     15.17CASS
21746611         71.89     72.50     73.51CASS
217566H1         39.28     40.50     42.60BURLEIGH
217566H2         20.76     20.00     18.77MORTON
217766I1         55.79     62.00     73.95GRAND FORKS
217666J1         52.59     52.00     51.01WARD
21196711         96.19     95.00     93.04MINNEHAHA
212067I1         16.97     16.50     15.73LAWRENCE
212067I2         16.23     20.00     28.44MEADE
212067I3         63.10     53.00     39.46PENNINGTON
212167S3         35.09     34.50     33.52BROWN
211967TE         12.11     12.60     13.45LINCOLN
21666864         51.47     46.00     38.10NATBONA
216568G1         23.58     24.50     26.09ALBANY
216568H2         65.30     59.50     50.92LARAMIE
216668R2         28.97     26.20     22.13FREMONT
2   27111       886.60    920.00    978.51MARICOPA
2   27121       336.99    340.00    345.07PIMA
217971G1         65.39     66.00     67.01COCHISE
2 5371H1         53.37     55.50     59.23COCONINO (PART-211)
213971H1         53.37     55.50     59.23COCONINO (WHOLE/PART IN 4 COR)
2   271I1        66.24     63.00     57.93PINAL
2 5271J1         57.07     62.00     71.19YUMA
229271R1         10.50     20.00     25.00MOHAVE(PART/WHOLE)
2 5471R2         33.24     34.40     36.41YAVAPAI
213971S1         41.34     46.00     54.98APACHE
2   271S2        26.87     26.70     26.40GILA
213971S5         46.67     49.30     54.01NAVAJO
2 667211        327.13    335.00    348.52KERN (PART/WHOLE)
2 657221        412.93    422.00    437.55FRESNO
2   47231      6836.25   6960.00   7171.22LOS ANGELES
2   47232      1186.90   1385.00   1794.87ORANGE
2 637241        612.92    625.00    645.66SACRAMENTO
2   47251       419.93    445.00    490.19RIVERSIDE (PART/WHOLE)
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2 707251         420.24    445.00    489.59RIVERSIDE (PART/WHOLE)
2   47252        646.32    670.00    711.42SAN BERNARDINO (PART/WHOLE)
2 627261        1239.03   1350.00   1558.02SAN DIEGO
2   57271       1028.58   1065.00   1128.59ALAMEDA
2   57272        521.92    565.00    645.00CONTRA COSTA
2   57273        192.51    206.00    230.65MARIN
2   57274        726.65    700.00    657.70SAN FRANCISCO
2   57275        538.91    551.00    571.75SAN MATEO
2   57276        165.22    175.00    192.62SOLANO
2   57281        930.16   1035.00   1237.48SANTA CLARA
2   47291        243.07    259.00    287.92SANTA BARBARA (PART/WHOLE)
2 717291         243.07    259.00    287.92SANTA BARBARA (PART/WHOLE)
2 6472A1         275.35    290.00    316.18SAN JOAQUIN
2 7072G1          81.70     77.00     69.74IMPERIAL
2 7472H1          62.76     66.00     71.76KINGS
2 7472H2         181.79    180.00    177.04TUIARE
2   572I2         78.41     83.00     91.25NAPA
2   572I3        182.23    197.00    224.36SONOMA
2 6572K1          42.55     42.50     42.40MADERA
2 6972K2         105.66    109.00    114.79MERCED
2 6772K3          17.73     18.90     21.01SAN BENITO
2 6472K4         180.36    192.00    213.10STANISLAUS (PART/WHOLE)
2 6972K4         180.36    192.00    213.10STANISLAUS (PART/WHOLE)
2 6772L1         234.06    250.00    279.04MONTEREY
2 6772L2         107.33    115.00    129.03SANTA CRUZ
2 7172M1          96.79     98.00    100.04SAN LUIS OBISPO
2   472N1        327.10    374.00    468.18VENTURA
2 637201          43.54     48.00     56.48YUBA
2 7372R1          98.18    100.00    103.09BUTTE
229372R4          39.50     44.70     49.00EL DORADO (PART/WHOLE)
2 6872R6         103.59     98.00     89.33HUMBOLDT
2 6372RA          73.47     79.00     89.16PLACER (PART/WHOLE)
2 7272RC          75.89     78.50     83.05SHASTA
2 7272RE          34.97     34.20     32.94SISKIYOU
2 6372RF          38.28     42.50     50.61SUTTER
2 7272RG          28.70     29.80     31.71TEHAMA
2 6372RI          82.17     88.00     98.66YOLO
22687311         608.22    665.00    771.95HONOLULU
226873R1          63.26     66.00     70.83HAWAII
226873R2            .25       .24       .22KALAWAO
226873R3          28.97     31.00     34.69KAUAI
226873R4          47.69     48.00     48.50MAUI
22927411         235.60    245.00    255.00CLARK
22937421         112.00    117.00    122.00WASHOE(PART/WHOLE)
229374H1           4.70      6.10      7.50DOUGLAS
229374H2           6.70      8.10      9.50LYON
229374H4            .50       .70       .90STORY
229274K1           3.80      4.90      6.00NYE  (PART/WHOLE)
21407511         125.71    131.50    141.74WEBER
21407521         122.04    130.00    144.45UTAH
21407531         453.97    460.00    470.22SALT LAKE
214075G1          88.79     96.50    110.88DAVIS
214175R1          29.04     27.00     23.89BOX ELDER
214175R2          41.28     43.30     46.87CACHE
213975S3           3.29      3.00      2.57GARFIELD (PART/WHOLE)
213975S6           2.57      2.40      2.13KANE     (PART/WHOLE)
213975S9           8.07      9.20     11.44SAN JUAN
213975SC           1.61      1.50      1.32WAYNE
2 5181S4          43.00     45.00     50.00YUKON 1970 ELEC. DIST. =26  (continued)
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 2 5081T2          95.00     101.30    106.00ANCHORAGE 1970 ELEC.DIS.=88
 2 5081T8           5.00       5.70      6.20PALMER 1970 ELEC. DIST.=9
 227082G1         102.39     101.50    100.02ADA
 227182H1          51.57      49.50     46.22BANNOCK
 227182J1          52.69      53.00     53.50BONNEVILLE
 214982R8          31.90      33.00     34.90KOOTEAI
 226982R9          23.66      25.20     27.97LATAH
 226982RB          29.95      30.80     32.26NEZ PERCE
 227082RC          12.63      12.70     12.80PAYETTE
 227182S2          29.69      29.10     28.13BINGHAM
 227082S5          60.59      61.50     63.03CANYON
 227182SF           4.54       5.30      6.85POWER
 227282SG          42.35      42.90     43.81TWIN FALLS
 2 908311          84.37      82.00     78.18YELLOWSTONE
 2 918321          83.67      81.00     76.73CASCADE
 2 9283G4          46.09      45.50     44.52SILVER BOW
 2 9283I1          17.07      15.40     12.95DEER LODGE
 2 9383I3          50.55      55.50     64.86MISSOULA
 2 9183R2           6.99       6.30      5.28CHOUTEAU
 2 9583R3          35.60      37.50     40.88FLATHEAD
 2 9683R4          28.69      30.10     32.59GALLATIN
 2 9483R9          31.51      33.10     35.92LEWIS AND CLARK
 2 9083S1          10.67      10.20      9.45BIG HORN
 2 388411         199.76     212.00    234.10LANE
 2 388421         144.06     166.00    210.54CLACKAMAS
 2 388422         549.76     557.00    569.26MULTONOMAH
 2 388423         123.26     146.00    194.08WASHINGTON
 2 3884G1          48.31      52.00     58.79BENTON
 210184H1          24.91      24.80     24.60CLATSOP
 2 3884I1          25.99      28.40     32.92COLUMBIA
 210484K1          49.00      49.00     49.00KLAMATH
 2 3884L1         139.74     148.00    162.86MARION
 210284M1          43.39      44.00     45.02UMATILLA
 2 3884R2          64.71      69.00     76.79LINN
 2 3884R3          32.09      33.00     34.57POLK
 2 3884R5          38.07      40.40     44.59YAMHILL
 210384U2          68.07      70.50     74.74DOUGLAS
 210384U3          87.04      91.00     98.00JACKSON
 210384U4          33.40      35.30     38.70JOSEPHINE
 2 388511         111.59     124.00    147.90CLARK
 2 168521        1080.20    1160.00   1306.57KING
 2 168522         219.79     253.00    320.33SNOHOMISH
 21498531         284.36     279.00    270.28SPOKANE
 2 168541         367.96     400.00    459.86PIERCE
 215285H1          68.83      72.50     79.04BENTON
 215285H2          25.40      27.50     31.38FRANKLIN
 2 1685I2          86.68      97.00    117.08KITSAP
 215185J1          23.46      25.50     29.29KITTITAS
 215085R8          52.77      53.50     54.72SKAGIT
 215085RA          75.10      80.00     88.89WHATCOM
 2 3885S1          63.95      69.50     79.85COWLITZ
 215485S2          57.88      62.50     71.03GRAY HARBOR
 215185SA         149.76     154.00    161.33YAKIMA
 226985T1          13.48      14.40     16.07ASOTIN
 215385T4          43.73      43.50     43.10WALLA WALLA
 226985T5          35.47      37.30     40.56WHITMAN
  3058ZZZ
9999                                                     END OF BATA BASE
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# APPENDIX X

## Assumed Emission Standards

# Appendix X

## Assumed Emission Standards

### I. INTRODUCTION

Under the Clean Air Act, as amended, air quality standards will be adopted for Air Quality Control Regions (AQCR's), then plans for implementation of the standards will be adopted. Ordinarily, implementation plans must include emission standards intended to permit a region to attain and maintain its established air quality standards. For this report, emission standards were selected without going through the above steps, which would have required many assumptions about air quality standards and a massive computational effort to derive appropriate emission standards for all the 298 metropolitan areas. The emission standards selected for this report are representative of those now used throughout the Nation.

### II. STANDARDS FOR PARTICULATES

For industrial process sources, the process weight rate regulation of the San Francisco Bay Area Pollution Control District (Table X-1) was used as the basis of control cost estimates. This regulation limits the weight of particulate emissions per hour as a function of the total weight of raw materials introduced into a process operation.

For incinerators, the New York State Incinerator Standard for new units was used. This standard limits total particulate emissions on the basis of mass rate (pounds/hour), rather than concentration. Several areas have adopted a variation of this; the New York State standard for new installations (Figure X-1) was used to determine the control efficiency of incinerators. For fuel-burning equipment, the combustion regulation of the State of Maryland was used (Figure X-2).

## III. STANDARDS FOR SULFUR OXIDES

For fuel-burning equipment, a regulation based on mass emission rate per million B.t.u. input was used. It allows an emission rate of 1.46 pounds of sulfur dioxide per million B.t.u. input; this limit is based on an equivalent sulfur content of 1.0 percent by weight in coal (1.38 percent by weight in oil). For process sources, a concentration standard of 500 parts per million of sulfur dioxide was used.

## IV. STANDARDS FOR HYDROCARBONS

For process sources, cost estimates were based on treatment of all exhaust gases to remove organic material by 90 percent (or more) by weight. For petroleum products storage, it was assumed that all stationary tanks, reservoirs, and containers with more than a 40,000-gallon capacity and a vapor pressure of 1.5 pounds per square inch absolute (or greater) must be equipped with floating roofs, vapor recovery systems, or other equally efficient devices. In addition, it was assumed that submerged filling inlets must be installed on all gasoline storage tanks with a capacity of 250 gallons or more.

## V. STANDARD FOR CARBON MONOXIDE

Cost estimates were based on treatment of all exhaust gases to remove or reduce the weight of carbon monoxide emissions by at least 95 percent.

## VI. STANDARDS FOR FLUORIDES

Three fluoride emission standards were utilized in this study. For the phosphate fertilizer and elemental phosphorus industries a standard of 0.2 pounds of total fluoride (gaseous and particulate) per ton of $P_2O_5$ was applied. For the aluminum industry a standard of 0.06 pounds of total fluoride per reduction cell per hour up to a maximum of 40 pounds per hour was applied. For the iron and steel and brick and tile industries, emission standards were applied separately to the gaseous and particulate fluoride fractions. For the gaseous fraction a standard of 95 percent removal was assumed. The standard for fluoride particulates requires that the quantity of total particulate emissions, including fluoride, meet the "process weight rate" standard.

## VII. STANDARD FOR LEAD PARTICULATES

The standard for lead particulates requires that the quantity of total particulate emission, including lead, meet the "process weight rate" standard.

## TABLE X-1. - ALLOWABLE RATE OF PARTICULATE EMISSION BASED ON PROCESS WEIGHT RATE*

| Process Weight Rate | | Rate of Emission | Process Weight Rate | | Rate of Emission |
|---|---|---|---|---|---|
| Lbs/hr | Tons/hr | Lbs/hr | Lbs/hr | Tons/hr | Lbs/hr |
| 100 | 0.05 | 0.551 | 16,000 | 8.00 | 16.5 |
| 200 | 0.10 | 0.877 | 18,000 | 9.00 | 17.9 |
| 400 | 0.20 | 1.40 | 20,000 | 10.00 | 19.2 |
| 600 | 0.30 | 1.83 | 30,000 | 15.00 | 25.2 |
| 800 | 0.40 | 2.22 | 40,000 | 20.00 | 30.5 |
| 1,000 | 0.50 | 2.58 | 50,000 | 25.00 | 35.4 |
| 1,500 | 0.75 | 3.38 | 60,000 | 30.00 | 40.0 |
| 2,000 | 1.00 | 4.10 | 70,000 | 35.00 | 41.3 |
| 2,500 | 1.25 | 4.76 | 80,000 | 40.00 | 42.5 |
| 3,000 | 1.50 | 5.38 | 90,000 | 45.00 | 43.6 |
| 3,500 | 1.75 | 5.96 | 100,000 | 50.00 | 44.6 |
| 4,000 | 2.00 | 6.52 | 120,000 | 60.00 | 46.3 |
| 5,000 | 2.50 | 7.58 | 140,000 | 70.00 | 47.8 |
| 6,000 | 3.00 | 8.56 | 160,000 | 80.00 | 49.0 |
| 7,000 | 3.50 | 9.49 | 200,000 | 100.00 | 51.2 |
| 8,000 | 4.00 | 10.4 | 1,000,000 | 500.00 | 69.0 |
| 9,000 | 4.50 | 11.2 | 2,000,000 | 1,000.00 | 77.6 |
| 10,000 | 5.00 | 12.0 | 6,000,000 | 3,000.00 | 92.7 |
| 12,000 | 6.00 | 13.6 | | | |

* Data in this table can be interpolated for process weight rates up to 60,000 lbs/hr by using equation $E=4.10\ P^{0.67}$ and can be interpolated and extrapolated for process weight rates in excess of 60,000 lbs/hr by using equation $E=55.0\ P^{0.11} - 40$ ($E$ = rate of emission in lbs/hr; $P$ = process weight rate in tons/hr).

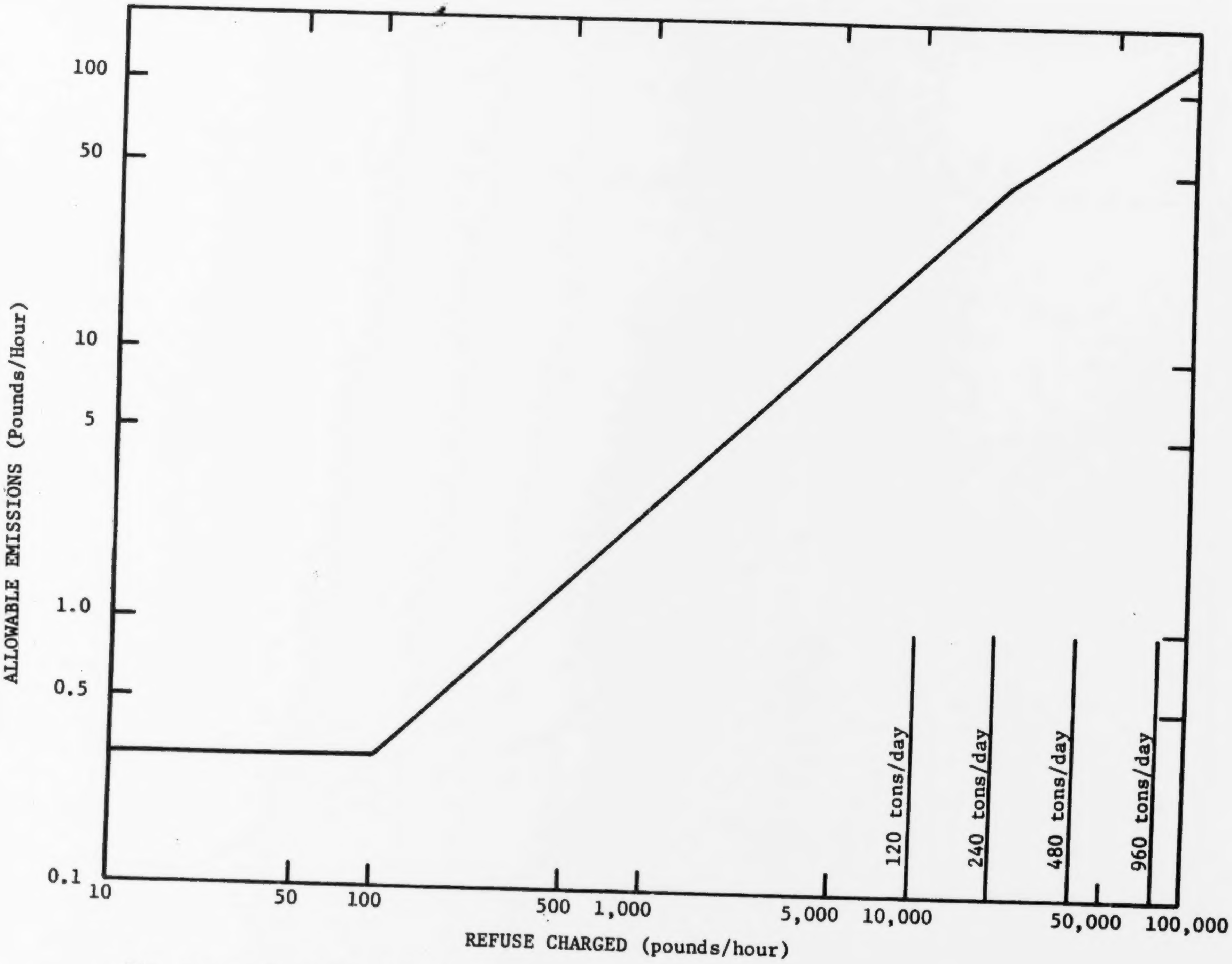

Fig. X-1. - New York State Particulate Emission Regulation for Refuse Burning Equipment

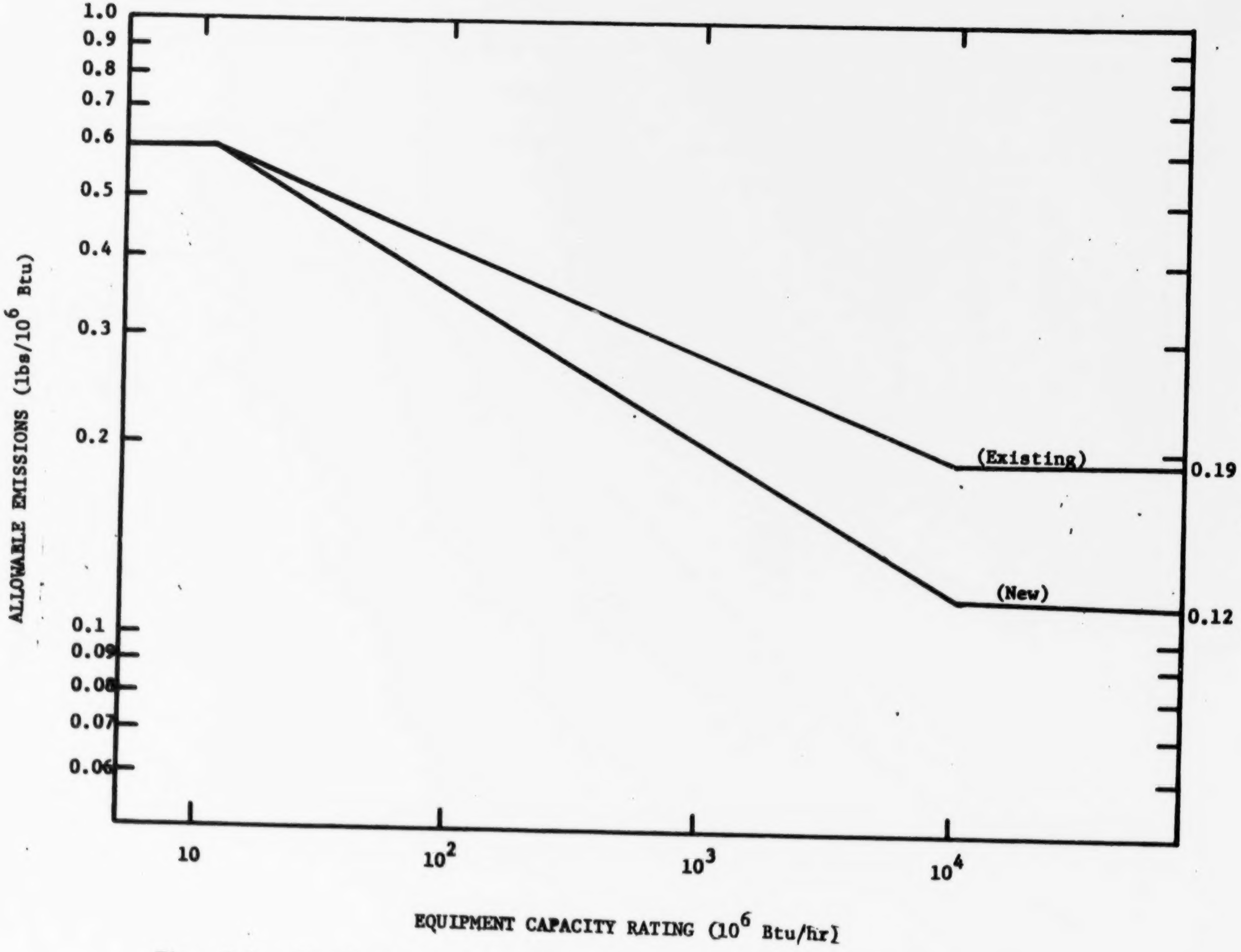

Fig. X-2. - Maryland Particulate Emission Standards for Fuel Burning Installations.